PERIPHYTON BIOASSESSMENT METHODS FOR MONTANA STREAMS

by

Loren L. Bahls, Ph.D.

September 1992
Revised January 1993

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TABLE OF CONTENTS

PREFACE TO JANUARY 1993 EDITION

Three significant changes have been made in this edition of *Periphyton Bioassessment Methods For Montana Streams*:

1. Separate sets of criteria have been developed for mountain streams and plains streams in Protocol I (screening protocol).

2. Biological integrity and overall impairment ratings are based on the **lowest** metric score rather than on the **average** metric score. This is because biological integrity, as defined by Karr and Dudley (1981), requires that species composition **and** diversity **and** and functional organization of the study community must all be comparable to undisturbed communities from natural habitats within the region. For example, a community with "poor" diversity but with "good" pollution and siltation indexes would still rate "poor" overall for biological integrity, and the stream would be considered severely impaired.

3. When both protocols are applied, results from Protocol II should be adopted because Protocol II is more sensitive to local conditions.

Please recycle the September 1992 edition and replace it with this document. Thank you.

L. L. Bahls
January 4, 1993

INTRODUCTION

This manual presents guidelines for using the composition and structure of periphyton communities to assess biological integrity and impairment of aquatic life in Montana streams. The manual recommends: (1) methods for collecting, processing and analyzing periphyton samples; (2) measurements or metrics for evaluating periphyton communities; and (3) biocriteria and protocols for assessing biological integrity and aquatic life impairment. This document also examines variability in the recommended metrics.

Two protocols are offered, one for screening stream sites based on ecoregional reference conditions and another for assessing impairment based on conditions at an upstream or sidestream control site. Both protocols distinguish among four levels of biological integrity and impairment of aquatic life.

Much of this manual is based on the findings of the 1990 Montana reference stream study (Bahls et al. 1992) and follow-up surveys conducted in 1991. Like the reference stream findings, these guidelines apply only to wadeable creeks and small rivers--second to sixth order streams as defined by Strahler (1957). The author is developing similar guidelines for lakes and wetlands.

Two sets of biocriteria are provided, one for mountain streams and one for plains streams. Although periphyton samples were collected from least-impaired reference streams in all six of the state's major ecoregions (Figure 1), there was relatively little variation in metric values among streams located within the same physiographic province (i.e., mountains and plains). There were, however, much larger differences in metric values between plains streams and mountain streams (Tables 2 and 4).

Periphyton biocriteria for mountain streams and plains streams may be equated with use classifications in the Montana Surface Water Quality Standards as follows. Mountain streams include those classified for "growth and propagation of salmonid fishes and associated aquatic life" (A, I, B-1, and C-1) and for "growth and *marginal* propagation of salmonid fishes and associated aquatic life" (B-2 and C-2). Plains streams are those classified for "growth and propagation of non-salmonid fishes and associated aquatic life" (B-3 and C-3).

This manual addresses only the structure and composition of stream periphyton communities. It does not address, at least directly, the other broad classes of ecological properties commonly used for assessing biological integrity: (1) health of individuals or populations; (2) trophic structure; and (3) system function.

The concept of biological integrity is the basis for biological assessment and the setting of ecological goals for water quality: "Biological integrity is the ability of an aquatic ecosystem to support and maintain a ... community of organisms having a species composition, diversity, and functional organization comparable to that of the natural habitats within a region" (Karr and Dudley 1981). **This definition makes the explicit assumption that natural, undisturbed systems are better than those affected by human activities.**

The State of Montana uses these numeric periphyton biocriteria as assessment tools but has yet to incorporate them into legally enforceable standards.

Plafkin et al. (1989) list several advantages of using algae for bioassessment:

1. Algae generally have rapid reproduction rates and very short life cycles, making them valuable indicators of short-term impacts. (Perennial and "fossil" algae, including expired but recognizable algae incorporated into the periphyton matrix, reflect longer term impacts.)

2. As primary producers, algae are most directly affected by physical and chemical factors.

3. Sampling is easy, inexpensive, requires few people, and creates minimal impact to resident biota.

4. Relatively standard methods exist for evaluation of functional and non-taxonomic structural characteristics (e.g., biomass and chlorophyll) of algal communities.

5. Algal communities are sensitive to some pollutants which may not visibly affect other aquatic communities, or may only affect other communities at higher concentrations (e.g., herbicides and inorganic nutrients).

Another advantage of algae is that they are ubiquitous in Montana surface waters and represented in unpolluted streams by large numbers of species and individuals. Heavy growths of algae are noticed by the public and usually perceived to be an indicator of inferior water quality.

SAMPLING

INDEX PERIOD

Summer (June 21 to September 21) is the preferred time for collecting periphyton from Montana streams and was the index period for establishing ecoregional reference conditions (Bahls et al. 1992). Periphyton diversity in Montana streams peaks in summer and early fall (Bahls et al. 1979a, 1979b, 1981; Ingman et al. 1979). Also, Montana streams generally have stable flows in summer, and summer is the most temperate and least troublesome time for aquatic field work in Montana.

High flows from snowmelt runoff may interfere with sampling in early summer. Sampling should be delayed for at least three weeks following high, bottom-scouring streamflows to allow for recolonization by algae and succession to a mature periphyton community (Peterson and Stevenson 1992).

It may be necessary to sample outside the summer period to coincide with flows in ephemeral or dewatered streams. This is particularly true for streams in the plains ecoregions and in the Montana Valley and Foothill Prairies ecoregion (Figure 1). However, community floristics and species richness, dominance, and diversity metrics generated from samples collected in fall, winter or spring may not be comparable to ecoregional reference conditions. For this reason only Protocol II (Control Site Protocol) is recommended for samples collected outside of the summer index period.

SITE SELECTION

Selection of study sites depends largely on the goals of the project. Factors to consider include access, location of contaminant sources, mixing of contaminants, and how typical the site is in terms of depth, gradient, substrate, and other physical conditions.

More restrictions apply to selection of a local reference or control site for Protocol II. The range of metric values used to define the "unimpaired" condition is based on the range of metric values from riffle to riffle within the same reach of reference stream. A reach is considered here to be a section of stream of uniform stream order as defined by Strahler (1957). **For this reason, the reference or control site must be located in the same reach as the study site or in a local tributary to the study stream that has the same stream order as the reach containing the study site.** As these requirements infer, either an upstream or sidestream control site may be used.

The local reference or control site need not be pristine, but it should be minimally disturbed compared to other sites in the catchment. Avoid areas of human disturbance and sites immediately below impoundments. Streamflow, depth, gradient, substrate, canopy cover and other conditions should be comparable to those at the study site. For the purpose of long-term monitoring, say during the operating life of a mine, the control site should be afforded sufficient protection to maintain existing water quality.

SAMPLE COLLECTION

Sample collection is recommended from natural substrates only. There are several reasons for this:

1. Artificial substrates require a return trip; this is a significant consideration in Montana, where the study stream may be 400 miles or more from the home office.

2. Artificial substrates are prone to loss, natural damage or vandalism.

3. The material of the substrate will influence the composition and structure of the community; solid artificial substrates will favor attached forms over motile forms and compromise the usefulness of the siltation index.

4. Orientation and length of exposure of the substrate will influence the composition and structure of the community.

5. The bulk of the periphyton community data collected to date by the State of Montana, including reference stream data, has been from natural substrates.

6. Periphyton communities collected from natural substrates integrate water quality conditions from the time the substrate was last scoured clean and pioneered with algae; this period of exposure is often longer than what is practical to obtain with artificial substrates.

Periphyton collection follows Procedure 6.2.2 in the Field Procedures Manual of the Montana Water Quality Bureau (DHES 1989). Microalgae (algae living as single cells or in microscopic colonies) are collected from natural substrates (rocks, logs, moss, mud) in proportion to the importance of those substrates at a given site, and these individual substrate collections are pooled in a common container. Collection of microalgae usually entails scraping the **entire surface** of several rocks of different sizes selected at random.

Portions of macroalgae (algae growing in large filaments or colonies visible to the naked eye) are collected in proportion to their abundance at the site and added to the common container. Macroalgae are collected both for determining community composition and as substrates for microalgae. While effort is usually concentrated in riffles, other macrohabitats (pools and runs) are also sampled if they support algae growth. The goal is to collect a single composite sample that is a miniature replica of the stand of algae that is present at that site.

A pocketknife or similar tool is useful for scraping rocks. A spoon or large-bore eyedropper may be used for lifting microalgae from mud or silt substrates. Macroalgae may be picked by hand. Epiphytic algae may be dislodged from macroalgae, moss and aquatic macrophytes by placing a portion of the higher plant in the sample container and shaking vigorously. The moss or macrophyte is then removed from the container and returned to the stream.

The sample container should be water tight, unbreakable, and have a wide mouth. Four ounces (125 ml) of capacity is usually sufficient. Enough ambient water should be added to the container to cover the sample. Then enough iodine potassium iodide (Lugol's solution) is added to impart a reddish-brown tint.

An identifying label should be firmly affixed to the outside of the container. At a minimum, the label should include stream name, location or site number, and date. Other information (legal description, other samples collected, relative abundance of substrates, dominant algae, higher plants, name of collector, environmental observations and measurements) should be recorded in a field notebook. Be careful to avoid spilling the contents of the preserved sample over the outside of the container because the Lugol's solution may cause the label to turn black, obscuring the recorded information.

Samples may be transported without refrigeration, but they should be kept dark and cold in a refrigerator until they are processed. If samples are stored for a long time, especially if they are stored at room temperature and in daylight, or if they contain a large amount of algae, the Lugol's solution should be replenished or replaced every few weeks.

SAMPLE PROCESSING AND ANALYSIS

The following methods for processing and analyzing periphyton samples have been used by biologists at the Montana Water Quality Bureau since 1973, for surveillance monitoring, intensive surveys, and fixed-station monitoring. These methods usually involve from 2 to 3 hours total elapsed time per sample. The two-step analysis provides (1) a ranking of non-diatom (soft-bodied) genera by relative volume (biomass) and (2) the percent relative abundance of individual diatom species. No effort is made to ascertain the proportion of dead (empty) diatom frustules because these are considered to be part of the "history" of the periphyton community from the time stream-bottom substrates were last scoured and pioneered with algae.

SOFT-BODIED ALGAE

The sample is poured into a shallow pan and small portions of conspicuous macroalgae are removed to a microscope slide having a shallow central basin. The remainder of the sample is returned to the sample jar and thoroughly agitated to randomize algae cells and colonies. Then, using a soda straw or large-bore pipette, a several-drop subsample of microalgae is added to the fragments of macroalgae in the shallow basin of the microscope slide. A coverslip is placed over the shallow basin, completing a composite wet mount. As time and resources allow, more than one wet mount may be prepared in this manner and analyzed as prescribed below in order to improve the reliability of ranking soft-bodied algae.

The wet mount is scanned under a compound microscope, first at 200X and then at 400X. Soft-bodied algae are identified to genus. After all of the common soft-bodied algae are identified, each genus is ranked according to its estimated contribution to the total algal **biomass** at the site, taking into account the remaining macroalgae and microalgae in the original sample and observations in the field notebook. The genus with the most biomass is ranked number 1; the genus with the next most biomass is ranked number 2, and so on. Diatoms are included, but they are ranked as a group (Class Bacillariophyceae) and not as individual genera. Genera that are rated rare (see below) are not ranked.

Genera of soft-bodied algae and diatoms as a group are also rated as to the relative abundance of their **cells**:

R (rare)	Fewer than one cell per field of view at 200X, on the average;
C (common)	At least one, but fewer than five cells per field of view;
VC (very common)	Between 5 and 25 cells per field;

A (abundant)	More than 25 cells per field, but countable;
VA (very abundant)	Number of cells per field too numerous to count.

These designations have no counterpart in terms of cells per unit area of stream bottom. Although the density of algal material in each wet mount will vary, a certain degree of standardization is achieved by the need to provide sufficient separation of cells and passage of light through the mount to allow for identification of genera and estimation of cell numbers.

The above information may be recorded in a lab notebook or on a bench sheet. Additional information should include stream name, site location or number, legal description, sample date, sample collector, sample analyst, date of analysis, and project name.

DIATOMS

The next step is to prepare the remainder of the sample for diatom analysis. The sample is thoroughly agitated once again to dislodge diatom epiphytes. Then about 25 ml of the sample is decanted **immediately** into a 100 ml glass beaker. Under a fume hood or out of doors, a small amount of concentrated sulfuric acid and then potassium dichromate is added to the beaker to oxidize the organic content of the sample, leaving behind inorganic sediment and "cleaned" diatom frustules. (**Caution!** The addition of sulfuric acid and dichromate will often cause a violent exothermic reaction.) Acid and dichromate are added until they no longer cause any visible reaction. No additional heat is necessary. Besides cleaning the frustules, this procedure breaks up diatom colonies and randomizes diatom cells.

The beaker is allowed to cool, then filled with distilled water and left to stand overnight. The supernatant is then poured off and the beaker is again filled with distilled water and this time left to stand a minimum of 4 hours. This procedure is repeated until all trace of color is gone from the supernatant. Using the cleaned residue, a permanent diatom strewn mount is prepared as described in "Standard Methods" (APHA et al. 1980).

The diatom slide is scanned under at least 900X using an oil immersion objective and condenser of 1.30 numerical aperture or greater. A list of species is compiled until the interval between discovery of additional species exceeds 3 to 5 minutes. The series of keys by Krammer and Lange-Bertalot (1986, 1988, 1991a, 1991b) is recommended for diatom identification. However, additional keys and a catalog of diatom species may be needed to identify all taxa present and to ascertain synonyms.

A diatom proportional count is then performed according to "Standard Methods" (APHA et al. 1980), counting between 350 and 450 diatom cells (frustules). Counts for each species are divided by the total count and multiplied by 100 to obtain percent relative abundance (PRA). Those species encountered in the floristic scan but not during the proportional count are designated with a "p" for "present".

Diatom species and raw counts should be recorded on a bench sheet along with ancillary information (stream name, site location or number, legal description, sample date, sample collector, sample analyst, date of analysis, project name). Electronic data storage and programs for calculating PRAs and metrics are also recommended.

QUALITY ASSURANCE

Quality assurance is more important for the diatoms than for the soft-bodied algae because diatoms are given much more weight in bioassessment. A measure of quality assurance can be obtained by making replicate diatom slides and having them analyzed by another phycologist. One replicate slide should be prepared and analyzed for every ten samples collected in a series. For sample sets smaller than ten, at least one diatom slide should be replicated and analyzed independently.

Two quality assurance objectives should be achieved:

1. All species accounting for 3% or more of the diatom frustules in each of the replicate slides should be correctly identified (synonyms are acceptable). Proportional counts for the two slides should be compared and differences in the identification of major species should be reconciled.

2. The percent community similarity index (Whittaker and Fairbanks 1958) calculated from proportional counts of the two replicate slides should exceed 75%. This figure is based on within-sample similarity index values calculated for 18 replicates from five reference streams sampled in 1990 (Table 1).

At this writing, the U. S. Environmental Protection Agency is drafting "Generic Quality Assurance Project Plan Guidance For Bioassessment/Biomonitoring Programs." When finished, this guidance will be consulted for additional or alternative quality assurance objectives that may be applied to these periphyton bioassessment methods.

METRICS

SOFT-BODIED ALGAE

Three metrics are recommended for soft-bodied or non-diatom algae: (1) dominant phylum; (2) indicator taxa; and (3) number of genera. Because the method for analyzing soft-bodied algae is largely qualitative and untested for reproducibility, these metrics should be used only in a supporting role to the diatom metrics and not as definitive accounts of biological integrity and aquatic life impairment.

Dominant Phylum

The dominant phylum is determined by calculating the cumulative weighted rank of non-diatom genera within each algal phylum. All of the common non-diatom genera in a sample are assigned ranks ranging from 1 to x, where x is the number of genera rated "common" to "very abundant" (see SAMPLE PROCESSING AND ANALYSIS). Those ranked number 1 score x points, those ranked number 2 score x-1 points, etc. The scores of all genera in each phylum are summed to arrive at the cumulative weighted rank. This figure gives a rough approximation of the relative biomass of each phylum. The determination of dominant phylum should be supported by field observations.

Blue-green algae dominated the non-diatom flora of Northern Rockies reference streams and green algae dominated the non-diatom flora of plains reference streams (Bahls et al. 1992). The two groups were co-dominants in streams of the Middle Rockies and the Montana Valley and Foothill Prairies.

Dominance by blue-green algae may be a function of the relatively small inorganic nitrogen values in streams of the Northern Rockies ecoregion. Bluegreens have a competitive advantage over other algae in such streams by being able to "fix" atmospheric or molecular nitrogen when bioavailable nitrogen in the ionic form (nitrate and ammonia) is in short supply. Larger concentrations of nitrogen tend to favor green algae. Hence dominance by green algae in mountain streams may indicate nitrogen enrichment.

Indicator Taxa

Certain genera of non-diatom algae can be used as indicators of different levels and causes of pollution. For example, large numbers of *Euglena* are almost always associated with moderate to heavy organic enrichment. Red algae, on the other hand, are common only in relatively pristine waters. *Audouinella* is a genus of red algae that occurs frequently in western Montana streams.

The literature on algal ecology is extensive (see Prescott 1968). The illustrated manual by Palmer (1977) is recommended as a useful general reference. Unfortunately, it is out of print.

Number of Genera

Like number of diatom species, the number of non-diatom genera in a periphyton community is inversely proportional to the degree of pollution. There are also regional differences in the number of non-diatom genera (Bahls et al. 1992). On average, fewer common non-diatom genera (and diatom species) were recorded in mountain reference streams than in plains reference streams (Table 2).

The smaller number of algal genera (and diatom species) in mountain streams is probably a function of the more severe natural conditions in these streams. Mountain streams tend to be steeper, faster, colder, darker and poorer in nutrients compared to plains streams. These harsh conditions may increase competition for resources and limit the number of algal niches available. An increase in nutrients in these streams may actually cause an **increase** in the number of non-diatom genera and diatom species.

DIATOMS

Values for a number of established and potential diatom metrics were calculated from data generated by the 1990 survey of Montana reference streams (Table 2). Some of these are redundant in that they communicate similar types of information. Four metrics, communicating four different types of information, were selected for development of biocriteria and bioassessment protocols.

Diversity Index

The Shannon diversity index (Weber 1973) was selected because it incorporates elements of both dominance (equitability) and species richness; it is sensitive to changes in water quality and has been used extensively in pollution studies worldwide, including Montana (Bahls 1979). An advantage of Shannon diversity over species richness is that it is not as sensitive to the number of frustules counted.

Pollution Index

A single pollution index is proposed as a shorthand method for summarizing the information contained in the three pollution tolerance groups of Lange-Bertalot (1979). The index is based on the decimal fraction of diatoms in each of the three groups: (1) most tolerant; (2) less tolerant; and (3) sensitive. This decimal

fraction is multiplied by the respective group number and the sum of these products is the pollution index. This number will range from 1.00 (all most-tolerant diatoms) to 3.00 (all sensitive diatoms).

Many of the common diatom taxa reported from Montana have been assigned to a pollution tolerance group (Appendix 1). Most of these taxa were assigned initially by Lange-Bertalot (1979). The remainder have been assigned by the author on the basis of published autecological profiles (Lowe 1974, Bahls et al. 1984) and unpublished Montana diatom distributions with concurrent ecological data. Not enough is known about the autecology of the other taxa to assign them to a group. Until this information is generated, unassigned taxa may be assigned to a group by default based on the genus to which it belongs (Appendix 2).

The autecological criteria for assigning diatom taxa to pollution tolerance groups are presented in Table 3. Several different contaminants (ecological variables) are considered. A taxon is assigned to the group which fits most of the ecological affinities for that taxon. Soil diatoms and aerophilic diatoms are assigned to group 2. The author solicits feedback from readers on both assigned and unassigned taxa.

Siltation Index

Nearly all of the diatoms that live on sediments are biraphidean and highly motile; most of these are in the orders Naviculales and Nitzschiales (Crumpton 1989). Among the genera of diatoms observed to have motile species (Werner 1977), *Navicula* and *Nitzschia* are by far the most common in Montana streams, both in number of species and number of individuals. Motile species are adapted to holding their position on unstable substrates, so the proportion of motile species or individuals in a sample may be directly related to the degree of sedimentation on the stream bottom.

The percent relative abundance of *Navicula* and *Nitzschia* species was chosen because it is potentially more sensitive to changes in sedimentation than the number of species in these genera. The less common but sometimes abundant motile genera *Surirella* and *Cylindrotheca* were not counted at any of the reference sites, but they may be included in this index when they appear at study sites. The siltation index will yield values ranging from 0.0 to 100.

Similarity Index

The percentage similarity index of Whittaker and Fairbanks (1958) is adopted because it is simple to calculate and because it incorporates information about all of the species that are counted. This index is simply the sum of the smaller of the two percent

relative abundance values for each species that is common to both the control site and the study site. (Species restricted to one or the other site are not tallied because the smaller of the two values will always be zero.) Theoretically, values for this index will range from 0.0 (totally different communities) to 100 (identical communities). This index should be used only with Protocol II because of the high floristic variability among ecoregional reference sites (Table 5).

METRIC VARIABILITY

Setting biocriteria for periphyton metrics requires an understanding of natural variation in metric values, as well as the response of metric values to various types and levels of pollution. This chapter explores the following types of natural variation: geographical (ecoregional); within samples; within reaches (between samples from separate riffles in the same reach); between reaches (of the same stream); and annual (year-to-year during the summer index period).

GEOGRAPHICAL

Tables 4 and 5 examine variability in selected diatom association indexes within mountain and plains ecoregions based on periphyton samples collected in 1990 from Montana reference streams. Table 4 is the basis for the ecoregional reference criteria used for screening study sites in Protocol I (Tables 10A and 10B).

The Montana reference stream study (Bahls et al. 1992) did not indicate a partitioning of metric values by the ecoregions of Omernik and Gallant (1987). Instead, periphyton data appeared to partition best into a mountain region and a plains region, with foothill streams more similar to mountain streams.

WITHIN SAMPLES

Table 1 shows variability in similarity index values between replicate slides prepared from periphyton samples collected from selected reference streams in 1990. These data may be used to set quality assurance goals for diatom proportional counts.

WITHIN REACHES

Tables 6 and 7 examine variability in selected diatom association indexes within reaches (among replicate riffles) of Montana reference streams sampled in 1990 and 1991. The control or local reference site biocriteria used in Protocol II (Table 12) are based in part on the degree of natural riffle-to-riffle variation indicated in these tables.

BETWEEN REACHES

Table 8 shows variability in similarity index values between adjacent reaches of the same stream for samples collected in 1991 from the Boulder River (2nd, 3rd and 4th order) and the West Fork Poplar River (2nd and 3rd order).

ANNUAL

Table 9 examines annual variability in selected diatom metrics at reference stream sites sampled in 1990 and 1991. This type of variability would need to be considered in evaluating data from long-term monitoring studies.

ASSESSMENT PROTOCOLS AND BIOCRITERIA

Two assessment protocols are offered: one for screening stream sites based on reference conditions established for the mountains and plains regions (Protocol I), and another for assessing impairment based on conditions at an upstream or sidestream control site (Protocol II). Both protocols distinguish among four levels of aquatic life impairment and biological integrity. Protocol I should be used only with metrics calculated from data collected during the summer index period. Protocol II can be applied to data collected at any time during the year.

If both protocols are used, results of Protocol II should be adopted. This is because Protocol II is more sensitive to local conditions, but only if the local control site is not impaired and closely represents the biological potential for the study stream.

PROTOCOL I: SCREENING PROTOCOL

This protocol assesses biological integrity and aquatic life impairment by comparing metric values from a study site to metric values derived from least-impaired reference streams in the same physiographic province (Tables 10A and 10B). Up to three diatom association indexes may be used in this protocol: (1) species diversity index (Shannon); (2) pollution index; and (3) siltation index. For each index, different potential conditions are recognized for mountain streams and plains streams as indicated by results from the reference stream study (Table 2). Hence, separate criteria have been developed for each group of streams.

Each index is assigned a score based on the value for that index in relation to the criteria in Table 10A or 10B. An individual rating is given for each index score. The **lowest** score establishes the overall biological integrity and impairment rating for the community of organisms at that site.

Diatom diversity in mountain streams tends to be smaller than diatom diversity in plains streams (Tables 2 and 4), and this difference is reflected in the lower criteria for mountain streams (Table 10A). Natural stress may result in unusually low diversity index values for streams that are pristine in all respects. This is often true for small mountain streams that have consistently cold water, steep gradients, and low levels of nutrients and light. *Achnanthes minutissima* often dominates the diatom flora of these streams. Streams dominated by this taxon and unimpaired by human activities may have Shannon diversity index values in the neighborhood of 2.00 (Water Quality Bureau, unpublished data).

For plains streams, lower values and criteria are considered normal for the pollution index and the siltation index (Tables 2 and 10B). Since few of the plains reference streams were unaffected by land management activities, a real but unknown amount

of human-caused impairment is probably built into these scoring criteria. In general, however, it is felt that these lower values for plains streams are more the result of natural factors than human-caused pollution. These natural factors include higher summer temperatures, larger concentrations of nutrients, sediments, and salts, lower stream gradient and more siltation.

Protocol I is tested in Table 11 on a number of streams suffering from different levels, sources and causes of impairment. This test shows that Protocol I may be relatively insensitive to impairment where sediment is the principal cause, e.g., Snake Creek, Thompson River, and Sun River. For other causes or combinations of causes, Protocol I appears to yield an accurate assessment of impairment.

PROTOCOL II: CONTROL SITE PROTOCOL

This protocol compares metric values from a study site to metric values from a local upstream or sidestream control site (Table 12). The control site must be of the same stream order as the study site. This protocol uses the three diatom association indexes used in Protocol I, plus the percent similarity index of Whittaker and Fairbanks (1958). This protocol is more sensitive than Protocol I because it compares against local reference conditions rather than against more generalized regional conditions. And unlike Protocol I, it can be applied year round.

The differential in metric values that is accepted in order to qualify for a "no impairment" or "excellent" rating is based on the observed within-reach variability of those metrics in selected reference streams (Tables 6 and 7). Scoring criteria for the remaining levels of impairment are apportioned accordingly.

Protocol II recognizes a possible two-way response by diatom diversity to different causes and degrees of impairment. Some mountain streams with naturally low diversity values are known to respond to an increase in sediment and/or nutrients with an **increase** in diversity (Table 13). These streams also experience an increase in the number of species counted. This response may help explain why plains streams, which have more sediment and nutrients than mountain streams (Bahls et al. 1992), also tend to have higher diversity values and species richness (Table 2). Presumably, much larger amounts of sediment and/or nutrients would reverse this trend and result in lower diversity values and fewer species, as do other pollutants. No intrinsic value is placed on this additional diversity because (1) the species added are more tolerant of pollution than preexisting species, and (2) it represents a deviation from the undisturbed condition for that site, which is the standard for "biological integrity" (Karr and Dudley 1981).

The siltation rating method in Protocol II puts a greater penalty on sediment increases at the lower end of the siltation scale. It is most sensitive when the control site has an index value of 20 or less. Above this value, the range of potential impairment is restricted. It is further restricted when the control site index is larger than 40. This is due to a mathematical artifact of the metric, which is the ratio of the reference site index to the study site index. For example, an increase of 45 units from a control site index of 5 to a study site index of 50 (a metric value of 10%) would yield a rating of "poor", whereas an increase of 45 units from a control site index of 50 to a study site index of 95 (a metric value of 53%) would yield a rating of "good".

Protocol II is tested in Table 13 on eight of the same streams that were used to test Protocol I in Table 11. The overall rating for four of these streams--Snake Creek, Sun River, Camas Creek, North Fork Dry Creek--was worse under Protocol II than under Protocol I, perhaps reflecting the greater sensitivity of Protocol II. However, the overall rating was better for the Clark Fork River below Missoula. In this case the "control" site was an upstream station on the Clark Fork. This stream is subject to some degree of impairment throughout its entire length, so the "control" site on the Clark Fork probably did not achieve the biological potential for the river. Using Protocol II, conditions at an impaired site will appear better if they are compared to conditions at another impaired site. This points out the importance of selecting a control site that approaches the biological potential for the study stream.

RECOMMENDATIONS

1. Develop or adopt a more rigorous method for measuring the number and biomass of genera of soft-bodied algae; develop criteria for measurements of soft-bodied algae.

2. Continue annual sampling at selected reference stream sites to better quantify year-to-year variation in diatom metrics.

3. Determine at what higher levels of sediment and/or nutrients the trend of increasing diversity and species richness is reversed.

4. Determine seasonal variation in diatom metrics at selected reference streams.

5. Determine or refine the ecological requirements of common diatom taxa reported from Montana; assign or reassign taxa to pollution tolerance groups.

6. Encourage efforts to standardize the taxonomic nomenclature and to assure the uniform identification of common diatoms found throughout North America.

ACKNOWLEDGEMENTS

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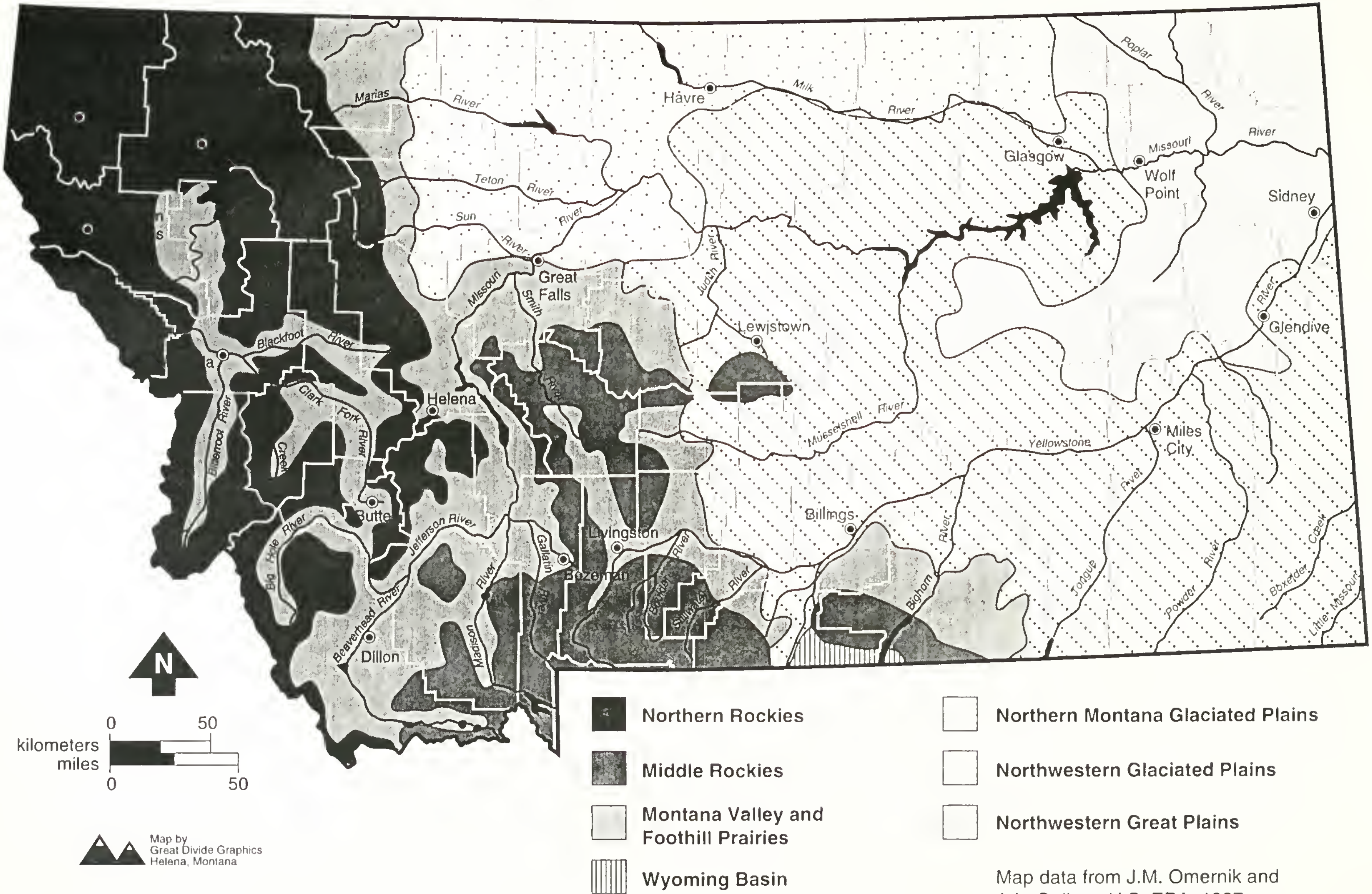
FIGURE AND TABLES

Figure 1. Ecoregions of Montana



Map data from J.M. Omernik and A.L. Gallant, U.S. EPA, 1987

Table 1. Variability in similarity index values calculated from diatom proportional counts conducted on replicate slides prepared from periphyton samples collected from selected reference streams in 1990.

Ecoregions	Number of Replicates	Mean	Range	Standard Deviation	Coefficient of Variation
Mountain Ecoregions	9	80.1	69.9 - 91.1	6.50	8.12%
Plains Ecoregions	9	80.8	75.2 - 87.3	4.47	5.53%

Table 2. Mean values and ranges for periphyton metrics from mountain and plains reference streams in Montana. PRA = Percent Relative Abundance.

Metric	Mountain Ecoregions[a]	Plains Ecoregions[b]
No. Common Nondiatom Genera	5 (1 - 10)	13 (9 - 19)
No. Diatom Species Counted	33 (23 - 51)	46 (34 - 57)
PRA Dominant Diatom Taxon	31.6 (11.1 - 67.0)	23.5 (17.8 - 37.9)
Diatom Species Diversity (Shannon)	3.58 (2.16 - 4.50)	4.31 (3.57 - 4.79)
PRA Most Tolerant Species (Group No. 1)	4.0 (0.4 - 10.8)	11.5 (6.6 - 24.2)
PRA Less Tolerant Species (Group No. 2)	18.8 (3.6 - 41.8)	56.7 (19.6 - 85.8)
PRA Sensitive Species (Group No. 3)	77.2 (52.5 - 96.2)	31.8 (3.8 - 73.8)
Pollution Index	2.72 (2.45 - 2.94)	2.20 (1.83 - 2.69)
No. *Navicula* + *Nitzschia* Species Counted	10 (0 - 21)	24 (11 - 34)
PRA *Navicula* + *Nitzschia* Species	14.5 (0.0 - 50.3)	51.4 (15.3 - 90.0)

[a]Total number of streams = 21 (includes Montana Valley and Foothill Prairies).

[b]Total number of streams = 9.

Table 3. Autecological criteria for assigning diatom taxa to pollution tolerance groups.

Ecological Variable	Pollution Tolerance Group 1	2	3
Nutrients[a]	Eutrophic	Mesotrophic	Oligotrophic
Organics[a]	Polysaprobic	Mesosaprobic	Oligosaprobic
Salts[a]	Euhalobus	Mesohalobous	Oligohalobous
Temperature[a]	Euthermal	Mesothermal	Oligothermal
Toxics[b]	Exceeds acute criterion	Exceeds chronic criterion but less than acute criterion	Less than chronic criterion
Substrate	Unstable Substrates (mud, silt, sand)	Mixed Substrates	Stable Substrates (rocks, plants)
Suspended Solids[c]	High (>80 mg/L)	Moderate (25-80 mg/L)	Low (<25 mg/L)

[a]Spectra for these variables are further defined by Lowe (1974).

[b]U. S. Environmental Protection Agency. 1986. Quality Criteria for Water. EPA 440/5-86-001.

[c]Federal Water Pollution Control Administration. 1968. Water Quality Criteria. U. S. Department of The Interior.

Table 4. Variability in selected diatom association indexes within mountain and plains ecoregions based on periphyton samples collected in 1990 from Montana reference streams.

Index	Statistic	Mountain Ecoregions	Plains Ecoregions
Shannon Diversity Index	number of streams	21	9
	mean	3.58	4.31
	range	2.16 - 4.50	3.57 - 4.79
	standard deviation	0.63	0.34
	coefficient of variation	17%	7.8%
Pollution Index	number of streams	21	9
	mean	2.72	2.20
	range	2.45 - 2.94	1.83 - 2.69
	standard deviation	0.16	0.28
	coefficient of variation	6.0%	12%
Siltation Index	number of streams	21	9
	mean	14.5	51.4
	range	0.0 = 50.3	15.3 - 90.0
	standard deviation	15.0	21.6
	coefficient of variation	93%	42%

Table 5. Variability in similarity index values among reference streams within each ecoregion/subregion based on samples collected in 1990 (pooled data).

Ecoregions	Number of Replicates	Mean	Range	Standard Deviation	Coefficient of Variation
Mountain Ecoregions	28	38.1	12.2 - 67.3	15.4	40.4%
Plains Ecoregions	12	27.9	11.7 - 42.3	10.3	36.8%

Table 6. The mean, range, standard deviation and coefficient of variation of selected diatom indexes between replicate riffles sampled in 1990 (n = 2).

Index	Stream:	Seymour Creek	N. Fork Teton R.	W. Fork Poplar R.[a]	Tongue River[a]	Battle Creek[a]	Mean C.V.
Shannon Diversity Index							
mean		4.44	2.86	4.38	3.53	3.83	
minimum		4.39	2.83	4.23	3.49	3.57	
maximum		4.49	2.89	4.52	3.57	4.08	
S. D.		0.07	0.04	0.21	0.06	0.36	
C. V.		1.6%	1.5%	4.7%	1.6%	9.4%	6.6%
Pollution Index							
mean		2.77	2.85	2.34	2.80	2.67	
minimum		2.76	2.76	2.23	2.76	2.65	
maximum		2.78	2.93	2.44	2.84	2.69	
S. D.		0.01	0.12	0.15	0.06	0.03	
C. V.		0.5%	4.2%	6.4%	2.2%	1.1%	2.8%
Siltation Index							
mean		12.3	1.85	48.7	13.2	20.4	
minimum		11.4	1.4	43.0	13.2	15.3	
maximum		13.2	2.3	54.4	13.2	25.5	
S. D.		1.3	0.6	8.1	0.0	7.2	
C. V.		10%	34%	17%	0.0	35%	19%
Similarity Index		80.7	67.9	58.9	73.2	68.1	

[a]Plains ecoregion.

Table 7. The mean, median, range, standard deviation and coefficient of variation of selected diatom indexes among replicate riffles in the Boulder and West Fork Poplar rivers, 1991 (n = 3).

Index	Stream: Reach:	Boulder 2nd Order	Boulder 3rd Order	Boulder 4th order	W.F. Poplar 2nd order[a]	W.F. Poplar 3rd order[a]	Mean C.V.
Shannon Diversity Index							
mean		4.13	4.37	4.06	4.91	3.36	
minimum		4.02	4.29	3.86	4.83	2.99	
median		4.08	4.38	4.15	4.87	3.48	
maximum		4.30	4.45	4.17	5.03	3.60	
S. D.		0.15	0.08	0.17	0.11	0.32	
C. V.		3.6%	1.8%	4.3%	2.2%	9.6%	4.3%
Pollution Index							
mean		2.69	2.43	2.72	1.93	2.29	
minimum		2.62	2.38	2.63	1.93	2.25	
median		2.69	2.43	2.73	1.93	2.30	
maximum		2.77	2.48	2.79	1.93	2.32	
S. D.		0.08	0.05	0.08	0.00	0.04	
C. V.		2.8%	2.1%	3.0%	0.0%	1.6%	1.9%
Siltation Index							
mean		13.30	27.90	13.37	66.23	64.33	
minimum		8.78	24.75	10.76	56.79	61.44	
median		13.73	26.35	12.29	69.48	63.57	
maximum		17.38	32.58	17.07	72.42	67.99	
S. D.		4.32	4.14	3.29	8.31	3.34	
C. V.		33%	15%	25%	13%	5.2%	18%
Similarity Index							
mean		66.0	81.0	77.0	59.9	70.1	
minimum		59.4	78.5	70.9	57.5	65.5	
median		64.9	81.5	77.2	58.7	65.6	
maximum		73.6	82.9	82.8	63.4	79.2	
S. D.		7.2	2.3	6.0	3.1	7.9	
C. V.		11%	2.8%	7.7%	5.2%	11%	7.6%

[a]Plains ecoregion.

Table 8. Variability in similarity index values between adjacent reaches of the Boulder and West Fork Poplar rivers in 1991.

Stream	Number of Replicates	Mean	Range	Standard Deviation	Coefficient of Variation
Boulder River	18	47.0	37.3 - 55.8	4.9	10%
West Fork Poplar River[a]	9	18.8	16.8 - 20.9	1.4	7.3%

[a]Plains ecoregion.

Table 9. The mean, range, standard deviation and coefficient of variation of selected metrics between years at reference stream sites sampled in 1990 and 1991 (n = 2).

Metric	Stream: Seymour Creek	S. Fk. Sun River	W. Fk. Stillwater River	Armstrong Spring Creek	Rock Creek[a]	Redwater River[a]	Mean C.V.
Shannon Diversity							
mean	4.13	3.18	2.77	3.96	4.13	4.22	
1990	4.39	3.39	2.48	3.93	4.11	4.35	
1991	3.87	2.96	3.05	3.98	4.15	4.09	
S. D.	0.37	0.30	0.40	0.04	0.03	0.18	
C. V.	8.9%	9.6%	15%	0.9%	0.7%	4.4%	6.5%
Pollution Index							
mean	2.79	2.80	2.90	2.68	1.95	2.17	
1990	2.76	2.82	2.94	2.57	1.83	2.11	
1991	2.89	2.77	2.85	2.78	2.06	2.22	
S. D.	0.10	0.04	0.06	0.15	0.16	0.08	
C. V.	3.7%	1.3%	2.2%	5.6%	8.4%	3.6%	4.1%
Siltation Index							
mean	13.0	6.7	1.2	29.5	87.5	56.2	
1990	13.2	8.2	1.1	29.9	90.0	64.4	
1991	12.7	5.2	1.2	29.0	84.9	47.9	
S. D.	0.4	2.1	0.1	0.6	3.6	11.7	
C. V.	2.8%	32%	6.2%	2.2%	4.1%	21%	11%
Similarity Index	60.7	53.5	67.5	65.9	37.2	34.1	

[a]Plains ecoregion.

Table 10A. Impairment ratings and scores for diatom association indexes from **mountain** streams when a local reference or control site is not available.

Score	Rating	Diversity Index	Pollution Index	Siltation Index
1	high stress	<1.00		
	severe pollution		<1.50	
	heavy siltation			>60
2	moderate stress	1.00 - 1.75		
	moderate pollution		1.50 - 2.00	
	moderate siltation			40 - 60
3	minor stress	1.76 - 2.50		
	minor pollution		2.01 - 2.50	
	minor siltation			20 - 39
4	no stress	>2.50		
	no pollution		>2.50	
	no siltation			<20

Lowest Score	Biological Integrity	Overall Impairment
1	poor	severe
2	fair	moderate
3	good	minor
4	excellent	none

Table 10B. Impairment ratings and scores for diatom association indexes from **plains** streams when a local reference or control site is not available.

Score	Rating	Diversity Index	Pollution Index	Siltation Index
1	high stress	<1.50		
	severe pollution		<1.00	
	heavy siltation			>80
2	moderate stress	1.50 - 2.50		
	moderate pollution		1.00 - 1.50	
	moderate siltation			70 - 80
3	minor stress	2.51 - 3.50		
	minor pollution		1.51 - 2.00	
	minor siltation			60 - 69
4	no stress	>3.50		
	no pollution		>2.00	
	no siltation			<60

Lowest Score	Biological Integrity	Overall Impairment
1	poor	severe
2	fair	moderate
3	good	minor
4	excellent	none

Table 11. Application of diatom assessment protocols to Montana streams impaired by various sources and causes of pollution when a local reference or control site is not available or not used.

Stream	Snake Creek	Thompson River near mouth	Sun R. below Muddy Creek	Camas Creek	West Fork Godfrey Cr.	Clark Fork R. below Missoula WWTP	Prickly Pear Cr. below Helena WWTP	N. Fork Douglas Cr. below Wasa Mine	Silver Bow Creek below Colorado Tailings	North Fork Dry Creek[a]	Luke Creek[a]	Libby Creek below Montanore Adit	German Creek below Beal Mountain Mine
Date Sampled	9-8-91	8-16-90	9-19-80	2-12-92	7-10-90	7-31-84	5-24-77	7-20-78	8-15-89	6-6-76	4-21-76	4-8-92	7-9-92
Source(s) of Impairment	Logging Slumps	Logging Roads Recreation	Irrigated Farming	Egg Farm	Dairy Farms	Missoula WWTP	Helena WWTP Grazing Natural	Mine Tailings	Mining Butte WWTP	Grazing	Dryland Farming	Mining	Mining
Cause(s) of Impairment	Sediment	Sediment	Sediment	Chicken Manure	Cow Manure Sediment	Municipal Wastewater	Municipal Wastewater Sediment	Metals Sediment	Metals Municipal Wastewater Sediment	Sediment Nutrients	Salinity (SC = 23,000 μmhos) sediment	Nutrients (nitrogen)	Sediment Nutrients (nitrogen)
Diversity Index (Score)	2.88 (4)	4.50 (4)	3.95 (4)	3.89 (4)	4.16 (4)	3.48 (4)	0.41 (1)	1.60 (2)	1.35 (2)	3.19 (3)	1.56 (2)	1.57 (2)	3.23 (4)
Pollution Index (Score)	2.78 (4)	2.56 (4)	2.69 (4)	1.95 (2)	1.77 (2)	1.82 (2)	1.02 (1)	1.97 (2)	1.47 (1)	1.97 (3)	1.02 (2)	2.95 (4)	1.79 (2)
Siltation Index (Score)	12.8 (4)	30.0 (3)	38.4 (3)	47.4 (2)	71.5 (1)	77.1 (1)	98.6 (1)	51.4 (2)	75.7 (1)	74.8 (2)	76.7 (2)	0.0 (4)	53.4 (2)
Lowest Score	4	3	3	2	1	1	1	2	1	2	2	2	2
Biological Integrity	Excellent	Good	Good	Fair	Poor	Poor	Poor	Fair	Poor	Fair	Fair	Fair	Fair

[a]Plains ecoregion.

Table 12. Impairment ratings and scores for diatom association indexes when a local reference or control site is available and used.

Score	Rating	Diversity Index[a]	Pollution Index[a]	Siltation Index[b]	Similarity Index[c]
1	high stress	<40% >160%			
	severe pollution		<50%		
	heavy siltation increase			<20%	
	very dissimilar communities				<20%
2	moderate stress	40 - 60% 140 - 160%			
	moderate pollution		50 - 70%		
	moderate siltation increase			20 - 40%	
	somewhat dissimilar communities				20 - 40%
3	minor stress	61 - 80% 120 - 139%			
	minor pollution		71 - 90%		
	small siltation increase			41 - 60%	
	somewhat similar communities				41 - 60%
4	no stress	>80% <120%			
	no pollution		>90%		
	no siltation increase			>60%	
	very similar communities				>60%

[a]Value is ratio of study site index to reference site index x 100.
[b]Value is ratio of reference site index to study site index x 100.
[c]Percent community similarity (Whittaker and Fairbanks 1958).

Lowest Score	Biological Integrity	Overall Impairment
1	poor	severe
2	fair	moderate
3	good	minor
4	excellent	none

Table [illegible]. Application of diatom assessment protocols to Montana streams impaired by various sources and causes of pollution when a local reference or control site is available.

Stream	Snake Cr.	Sun R. below Muddy Cr.	Camas Cr.	Clark Fk. R. below Missoula WWTP	Prickly Pear Cr. below Helena WWTP	North Fk. Dry Creek[d]	Libby Cr. below Montanore Adit	German Cr. below Beal Mountain Mine
Date Sampled	09-08-91	09-19-80	02-12-92	07-31-84	05-24-77	06-06-76	04-08-92	07-09-92
Source(s) of Impairment	Logging Slumps	Irrigated Farming	Egg Farm	Missoula WWTP	Helena WWTP Grazing Natural	Grazing	Mining	Mining
Cause(s) of Impairment	Sediment	Sediment	Chicken Manure	Municipal Wastewater	Municipal Wastewater Sediment	Sediment Nutrients	Nutrients (nitrogen)	Sediment Nutrients (nitrogen)
Diversity Index Ratio (Score)	139% (3)	150% (2)	168% (1)	93% (4)	15% (1)	85% (4)	74% (3)	76% (3)
Pollution Index Ratio (Score)	96% (4)	100% (4)	67% (2)	70% (2)	54% (2)	99% (4)	100% (4)	68% (2)
Siltation Index Ratio (Score)	3% (1)	19% (1)	3% (1)	45%[a] (3)	30%[a] (2)	74%[b] (4)	100%[c] (4)	48%[a] (3)
Similarity Index (Score)	64% (4)	29% (2)	26% (2)	34% (2)	7% (1)	15% (1)	30% (2)	24% (2)
Lowest Score	1	1	1	2	1	1	2	2
Biological Integrity	Poor	Poor	Poor	Fair	Poor	Poor	Fair	Fair

[a]Reference site index was >20.
[b]Reference site index was >40.
[c]Siltation index of both reference site and study site was 0.0.
[d]Plains ecoregion.

Appendix 1

Pollution Tolerance Class Assignments For Diatom Taxa Reported From Montana

DIATOM TAXA REPORTED FROM MONTANA

ID #:	SYN. OF	GENUS:	SPECIES/VARIETY:	AUTHOR:	POL.CL.
D0001		Achnanthes	aapajarvensis	A. Cl.	
D0002	D0070	Achnanthes	affinis	Grun.	3
D0003		Achnanthes	amphicephala	Hust.	
D0004		Achnanthes	antigua	M. Perag.	
D0005		Achnanthes	arcuata	A. Cl.	
D0006		Achnanthes	austriaca	Hust.	
D0007		Achnanthes	bergiani	A. Cl.	
D0008		Achnanthes	biasolettiana	(Kutz.) Grun.	3
D0009		Achnanthes	bicapitellata	A. Cl.	
D0010		Achnanthes	biconfusa	VanLan.	
D0093		Achnanthes	bioretii	Germain	3
D0011		Achnanthes	borealis	A. Cl.	
D0012		Achnanthes	brevipes	Agardh	
D0013		Achnanthes	calcar	Cl.	3
D0014		Achnanthes	chilensis v. subaequalis	Reim.	
D0015		Achnanthes	clevei	Grun.	3
D0016		Achnanthes	clevei v. rostrata	Hust.	3
D0017		Achnanthes	coarctata	(Breb. in W. Sm.) Grun.	
D0018		Achnanthes	conspicua	A. Mayer	
D0019		Achnanthes	conspicua v. brevistriata	Hust.	
D0020		Achnanthes	curta	(A. Cl.) A. Berg	
D0098		Achnanthes	daonensis	Lange-Bertalot	3
D0021	D0008	Achnanthes	deflexa	Reim.	3
D0022		Achnanthes	delicatula	(Kutz.) Grun.	2
D0023		Achnanthes	depressa	(Cl.) Hust.	
D0024		Achnanthes	dicephala	nomina nuda	
D0025		Achnanthes	didyma	Hust.	
D0026		Achnanthes	diversa	A. Cl.	
D0027		Achnanthes	exigua	Grun.	3
D0028		Achnanthes	exigua v. constricta	(Grun.) Hust.	3
D0029		Achnanthes	exigua v. heterovalva	Krasske	3
D0030		Achnanthes	exigua v. lanceolata	nomina nuda	3
D0031	D0070	Achnanthes	exilis	Kutz.	
D0032		Achnanthes	flexella	(Kutz.) Brun	3
D0033		Achnanthes	gibberula	Grun.	
D0034		Achnanthes	grimmei	Krasske	
D0035		Achnanthes	groenlandica	(Cl.) Grun.	
D0036		Achnanthes	harveyi	Reim.	
D0037		Achnanthes	hauckiana	Grun.	2
D0038		Achnanthes	hauckiana v. rostrata	Schulz	2
D0039		Achnanthes	hungarica	(Grun.) Grun.	2
D0040		Achnanthes	hustedtii	(Krasske) Reim.	3
D0041		Achnanthes	inflata	(Kutz.) Grun.	
D0042		Achnanthes	kolbei	Hust.	
D0043		Achnanthes	kriegeri	Krasske	
D0044		Achnanthes	kryophila	Petersen	3
D0045		Achnanthes	lacunarum	Hust.	
D0092		Achnanthes	laevis	Oestrup	3
D0046		Achnanthes	lanceolata	Breb. ex Kutz.	2
D0047		Achnanthes	lanceolata v. apiculata	Patr.	2
D0048		Achnanthes	lanceolata v. dubia	Grun.	2
D0049		Achnanthes	lanceolata v. elliptica	Cl.	2
D0050		Achnanthes	lanceolata v. haynaldii	(Istv.-Schaarsch.) Cl.	2
D0051		Achnanthes	lanceolata v. lanceolatoides	(Sov.) Reim.	2
D0052	D0049	Achnanthes	lanceolata v. omissa	Reim.	2
D0053		Achnanthes	lanceolata v. rhomboidalis	A. Mayer	2

DIATOM TAXA REPORTED FROM MONTANA

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D0054	D0048	Achnanthes	lanceolata v. rostrata	(Ostr.) Hust.	2
D0094		Achnanthes	lapidosa	Krasske	3
D0055	D0092	Achnanthes	lapponica	(Hust.) Hust.	3
D0056	D0092	Achnanthes	lapponica v. ninckei	(Guerm. et Mang.) Reim.	3
D0057		Achnanthes	laterostrata	Hust.	3
D0058		Achnanthes	lemmermanni	Hust.	
D0059	D0065	Achnanthes	levanderi	Hust.	3
D0060	D0099	Achnanthes	lewisiana	Patr.	
D0061		Achnanthes	linearis	(W. Sm.) Grun.	3
D0062		Achnanthes	linearis f. curta	H. L. Sm.	3
D0063	D0096	Achnanthes	linearis v. pusilla	Grun.	3
D0064		Achnanthes	longiceps	Ehr.	
D0065		Achnanthes	marginulata	Grun.	3
D0066	D0032	Achnanthes	maxima	A. Cl.	3
D0067	D0032	Achnanthes	maxima v. lanceolata	(Ostr.)	3
D0068		Achnanthes	microcephala	(Kutz.) Grun.	3
D0069	D0032	Achnanthes	minuta	(Cl.) A. Cl.	3
D0070		Achnanthes	minutissima	Kutz.	3
D0071	D0070	Achnanthes	minutissima v. cryptocephala	Grun.	3
D0072		Achnanthes	minutissima v. microcephala	Grun.	3
D0073		Achnanthes	montana	Krasske	
D0091		Achnanthes	nodosa	A. Cl.	
D0074		Achnanthes	oestrupi	(A. Cl.) Hust.	
D0075		Achnanthes	parva	Sov.	
D0076		Achnanthes	peragalli	Brun et Herib.	
D0077		Achnanthes	peragalli v. fossilis	Temp. et Perag.	
D0078		Achnanthes	peragalli v. parvula	(Patr.) Reim.	
D0095		Achnanthes	petersenii	Hustedt	3
D0079		Achnanthes	pinnata	Hust.	
D0080		Achnanthes	plonensis	Hust.	
D0081		Achnanthes	praerupta	nomina nuda	
D0096		Achnanthes	pusilla	(Grun.) De Toni	3
D0082	D0070	Achnanthes	reimeri	Camburn	
D0083	D0065	Achnanthes	rupestris	Krasske	
D0084		Achnanthes	saxonica	Krasske	
D0085		Achnanthes	scutellum	nomina nuda	
D0086		Achnanthes	stewartii	Patr.	
D0097		Achnanthes	subatomoides	(Hustedt) L.-B. & Archibald	3
D0087		Achnanthes	sublaevis v. crassa	Reim.	
D0088	D0094	Achnanthes	subrostrata	Hust.	
D0089	D0094	Achnanthes	subrostrata v. appalachiana	Camburn et Lowe	
D0099		Achnanthes	suchlandtii	Hust.	3
D0090		Achnanthes	wellsiae	Reim.	
D0200		Amphipleura	lindheimeri	Grun.	
D0201		Amphipleura	pellucida	(Kutz.) Kutz.	2
D0300		Amphora	acutiuscula	Kutz.	1
D0301		Amphora	bullatoides	Hohn et Hellerman	
D0302		Amphora	coffeiformis	(Ag.) Kutz.	1
D0303		Amphora	delicatissima	Krasske	1
D0315		Amphora	dusenii	Brun.	2
D0304		Amphora	fogediana	Krammer	3
D0305		Amphora	inariensis	Krammer	3
D0316		Amphora	libyca	Ehr.	3
D0306		Amphora	lineolata	Ehr.	1
D0307		Amphora	normanii	Rabh.	2
D0308		Amphora	ovalis	(Kutz.) Kutz.	3

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D0309	D0316	Amphora	ovalis v. affinis	(Kutz.) V.H. ex DeT.	3
D0310	D0311	Amphora	ovalis v. pediculus	(Kutz.) V.H. ex DeT.	3
D0311		Amphora	pediculus	(Kutz.) Grun.	3
D0312		Amphora	perpusilla	(Grun.) Grun.	3
D0313		Amphora	submontana	Hust.	3
D0314		Amphora	veneta	Kutz.	1
D0400		Anomoeoneis	brachysira v. zellensis	(Grun.) Krammer	3
D0401		Anomoeoneis	costata	(Kutz.) Hust.	1
D0402		Anomoeoneis	serians	(Breb. ex Kutz.) Cl.	3
D0403		Anomoeoneis	serians v. brachysira	(Breb. ex Kutz.) Hust.	3
D0404		Anomoeoneis	sphaerophora	(Ehr.) Pfitz.	2
D0405		Anomoeoneis	sphaerophora v. guntheri	O. Mull.	2
D0406		Anomoeoneis	sphaerophora v. sculpta	O. Mull.	2
D0407		Anomoeoneis	vitrea	(Grun.) Ross	2
D0409		Anomoeoneis	vitrea f. lanceolata	(A. Mayer) Moghadam	2
D0408		Anomoeoneis	vitrea v. gomphonemacea	(Grun.) Moghadam	2
D0410		Anomoeoneis	zellensis	(Grun.) Cl.	3
D0500		Asterionella	formosa	Hass.	3
D0550		Aulacoseira	alpigena	(Grun.) Krammer	3
D0551		Aulacoseira	ambigua	(Grun.) Simonsen	3
D0552		Aulacoseira	distans	(Ehr.) Simonsen	3
D0553		Aulacoseira	granulata	(Ehr.) Simonsen	3
D0554		Aulacoseira	islandica	(O.Mull.) Simonsen	3
D0555		Aulacoseira	italica	(Ehr.) Simonsen	3
D0556		Aulacoseira	lirata	(Ehr.) Ross	3
D0557		Aulacoseira	perglabra	(Oestrup) Haworth	3
D0558		Aulacoseira	pfaffiana	(Reinsch) Krammer	3
D0600		Bacillaria	paradoxa	Gmelin	2
D0650	D2858	Berkella	linearis	Ross et Sims	3
D0700	D4950	Biddulphia	laevis	Ehr.	2
D0800	D0810	Caloneis	alpestris	(Grun.) Cl.	
D0801		Caloneis	amphisbaena	(Bory) Cl.	2
D0802		Caloneis	bacillaris	(Greg.) Cl.	
D0803		Caloneis	bacillaris v. thermalis	(Grun.) A. Cl.	
D0804		Caloneis	bacillum	(Grun.) Cl.	2
D0805		Caloneis	bacillum v. lancettula	(Schulz) Hust.	2
D0806		Caloneis	clevei	(Lagst.) Cl.	
D0807		Caloneis	hyalina	Hust.	
D0808		Caloneis	lewisii	Patr.	
D0809		Caloneis	lewisii v. inflata	(Schultze) Patr.	
D0810		Caloneis	limosa	(Kutz.) Patr.	
D0818		Caloneis	silicula	(Ehr.) Cleve	2
D0820		Caloneis	tenuis	(Gregory) Krammer	3
D0811	D0810	Caloneis	trochus v. linearis f. fasciata	(Hust.) Mayer	
D0819		Caloneis	undulata	(Gregory) Krammer	3
D0812	D0818	Caloneis	ventricosa	(Ehr.) Meist.	2
D0813		Caloneis	ventricosa v. alpina	(Cl.) Patr.	
D0814		Caloneis	ventricosa v. minuta	(Grun.) Mills	
D0815		Caloneis	ventricosa v. subundulata	(Grun.) Patr.	
D0816		Caloneis	ventricosa v. truncatula	(Grun.) Meist.	
D0817		Caloneis	zachariasi	Reichelt	
D0900		Campylodiscus	clypeus	Ehr.	
D0901		Campylodiscus	noricus	Ehr.	
D0902		Campylodiscus	noricus v. hibernica	(Ehr.) Grun.	
D1000		Chaetoceros	elmorei	Boyer	1
D1001		Chaetoceros	muelleri	Lemmermann	1

DIATOM TAXA REPORTED FROM MONTANA

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D1100		Cocconeis	cholnokyana	A. Cl.	
D1101		Cocconeis	diminuta	Pantocsek	
D1102		Cocconeis	disculus	(Schum.) Cl.	
D1103		Cocconeis	fluviatilis	Wallace	
D1104		Cocconeis	klamathensis	Sov.	
D1105		Cocconeis	pediculus	Ehr.	3
D1106		Cocconeis	placentula	Ehr.	3
D1107		Cocconeis	placentula v. euglypta	(Ehr.) Cl.	3
D1108		Cocconeis	placentula v. lineata	(Ehr.) V. H.	3
D1109		Cocconeis	rugosa	Sov.	
D1110		Cocconeis	scutellum	Ehr.	
D1111		Cocconeis	scutellum f. parva	Grun. in V. H.	
D1112		Cocconeis	thumensis	A. Mayer	
D1200		Coscinodiscus	marginatus	Ehr.	
D1201		Coscinodiscus	rothii	(Ehr.) Grun.	
D1251		Cyclostephanos	dubius	(Fricke) Round	2
D1250		Cyclostephanos	tholiformis	Stoermer, Hakansson & Theriot	2
D1300		Cyclotella	antiqua	W. Smith	
D1301		Cyclotella	atomus	Hust.	2
D1302		Cyclotella	bodanica	Eulenstein	
D1303		Cyclotella	bodanica v. lemanensis	O. Mull.	
D1304		Cyclotella	catenata	Brun	
D1305		Cyclotella	comensis	Grun. in V. H.	
D1306		Cyclotella	comta	(Ehr.) Kutz.	2
D1320		Cyclotella	glabriuscula	(Grun.) Hakansson	3
D1307		Cyclotella	glomerata	Bachmann	2
D1308		Cyclotella	kutzingiana	Thwaites	2
D1309		Cyclotella	kutzingiana v. planetophora	Fricke	2
D1310		Cyclotella	kutzingiana v. radiosa	Fricke	2
D1311		Cyclotella	kutzingiana v. schumanni	Grun. in V. H.	2
D1312		Cyclotella	meneghiniana	Kutz.	2
D1313		Cyclotella	michiganiana	Skv.	
D1314		Cyclotella	ocellata	Pantocsek	
D1315		Cyclotella	operculata	(Ag.) Kutz.	
D1316		Cyclotella	pseudostelligera	Hust.	2
D1317		Cyclotella	stelligera	Cl. et Grun.	3
D1318		Cyclotella	striata	(Kutz.) Grun.	1
D1319		Cyclotella	striata v. bipunctata	Fricke.	1
D1400		Cylindrotheca	gracilis	(Breb.) Grun.	2
D1500		Cymatopleura	cochlea	Brun	2
D1501		Cymatopleura	elliptica	(Breb.) W. Sm.	2
D1502		Cymatopleura	elliptica v. nobilis	(Hantzsch) Hust.	2
D1503		Cymatopleura	solea	(Breb.) W. Sm.	2
D1504		Cymatopleura	solea v. apiculata	(W. Sm.) Ralfs	2
D1505		Cymatopleura	solea v. regula	(Ehr.) Grun.	2
D1671	D1648	Cymbella	Species 1		3
D1600		Cymbella	aequalis	W. Sm.	
D1601		Cymbella	affinis	Kutz.	3
D1602		Cymbella	alpina	Grun.	
D1603		Cymbella	amphicephala	Naegeli ex Kutz.	3
D1604		Cymbella	angustata	(W. Sm.) Cl.	3
D1605		Cymbella	aspera	(Ehr.) H. Perag.	3
D1606		Cymbella	brehmii	Hust.	
D1676		Cymbella	caespitosa	(Kutz.) Brun	2
D1607		Cymbella	capitata	Brun	
D1608		Cymbella	cesatii	(Rabh.) Grun. ex A. S.	3

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D1609		Cymbella	cistula	(Ehr.) Kirchn.	3
D1610		Cymbella	cistula v. gibbosa	Brun	3
D1611		Cymbella	cuspidata	Kutz.	
D1612		Cymbella	cymbiformis	Ag.	3
D1613		Cymbella	cymbiformis v. nonpunctata	Font.	3
D1614		Cymbella	delicatula	Kutz.	3
D1615		Cymbella	delicatula v. intermedia	McCall	3
D1616		Cymbella	diluviana	(Krasske) Florin	
D1617	D1627	Cymbella	ehrenbergii	Kutz.	
D1675		Cymbella	falaisensis	(Grun.) Krammer & Lange-Bertalot	3
D1618		Cymbella	fluminea	Patr. et Freese	
D1619		Cymbella	gracilis	(Ehr.) Kutz.	
D1620		Cymbella	hauckii	V. H.	
D1621		Cymbella	hebridica	Grun. ex Cl.	
D1622		Cymbella	helvetica	Kutz.	3
D1623		Cymbella	heteropleura	(Ehr.) Kutz.	
D1624		Cymbella	heteropleura v. subrostrata	Cl.	
D1625		Cymbella	hustedtii	Krasske	
D1626		Cymbella	hybrida	Grun. ex Cl.	
D1627		Cymbella	inaequalis	(Ehr.) Rabh.	
D1628		Cymbella	lacustris	(Ag.) Cl.	
D1629		Cymbella	laevis	Naegeli ex Kutz.	
D1630		Cymbella	lanceolata	(Ag.) Ag.	
D1631		Cymbella	lata	Grun.	
D1632		Cymbella	leptoceros	(Ehr.) Grun.	
D1633	D1619	Cymbella	lunata	W. Sm.	
D1672		Cymbella	mesiana	Cholnoky	3
D1634		Cymbella	mexicana	(Ehr.) Cl.	3
D1635		Cymbella	mexicana v. janischii	(A. S.) Reim.	3
D1636		Cymbella	microcephala	Grun.	2
D1637		Cymbella	microcephala v. crassa	Reim.	2
D1638		Cymbella	minuta	Hilse ex Rabh.	2
D1639		Cymbella	minuta f. latens	(Krasske) Reim.	2
D1640	D1672	Cymbella	minuta v. pseudogracilis	(Choln.) Reim.	3
D1641	D1673	Cymbella	minuta v. silesiaca	(Bleisch ex Rabh.) Reim.	3
D1642		Cymbella	muelleri	Hust.	2
D1644		Cymbella	muelleri f. ventricosa	(Temp. et Perag.) Reim.	2
D1643	D1642	Cymbella	muelleri v. javanica	(Hust.) Hust.	2
D1645		Cymbella	naviculiformis	(Auersw. ex Heib.)	3
D1646		Cymbella	obtusiuscula	(Kutz.) Grun.	
D1647	D1613	Cymbella	parva	(W. Sm.) Cl.	
D1648		Cymbella	perpusilla	A. Cl.	3
D1649		Cymbella	prostrata	(Berkeley) Cl.	3
D1650	D1676	Cymbella	prostrata v. auerswaldii	(Rabh.) Reim.	2
D1651		Cymbella	pusilla	Grun.	1
D1674		Cymbella	reichardtii	Krammer	3
D1652		Cymbella	reinhardtii	Grun.	3
D1653	D1662	Cymbella	rhomboidea	Boyer	
D1654		Cymbella	rupicola	Grun.	
D1655		Cymbella	ruttneri	Hust.	
D1673		Cymbella	silesiaca	Bleisch in Rabenhorst	3
D1656	D1616	Cymbella	similis	Patr.	
D1657		Cymbella	sinuata	Greg.	3
D1658		Cymbella	sinuata f. ovata	Hust.	3
D1659		Cymbella	stauroneiformis v. capitata	A. Cl.	
D1660		Cymbella	stuxbergii v. siberica	(Grun.) Wislouch	

DIATOM TAXA REPORTED FROM MONTANA

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D1661		Cymbella	subaequalis	Grun.	
D1662		Cymbella	triangulum	(Ehr.) Cl.	3
D1663		Cymbella	tumida	(Breb. ex Kutz.) V. H.	3
D1664		Cymbella	tumidula	Grun. ex A. S.	
D1665	D1640	Cymbella	turgida	(Greg.) Cl.	
D1666		Cymbella	turgidula	Grun.	3
D1667	D1638	Cymbella	ventricosa	Kutz.	2
D1668		Cymbella	ventricosa v. girodi	(Herib.) H. Kobayashi	
D1669		Cymbella	ventricosa v. ovata f. minor	A. Cl.	
D1670	D1673	Cymbella	ventricosa v. silesiaca	(Bleisch ex Rabh.) A. Cl.	3
D1800		Cymbellonitzschia	diluviana	Hust.	3
D1900		Denticula	elegans	Kutz.	
D1901		Denticula	elegans f. valida	Pedic.	
D1907		Denticula	kuetzingii	Grun.	
D1902		Denticula	rainierensis	Sov.	
D1903		Denticula	subtilis	Grun.	
D1904		Denticula	tenuis	Kutz.	3
D1905		Denticula	tenuis v. crassula	(Naeg. ex Kutz.)	3
D1906		Denticula	thermalis	Kutz.	
D2000		Diatoma	anceps	(Ehr.) Kirchn.	3
D2001		Diatoma	anceps v. linearis	M. Perag.	3
D2002	D2005	Diatoma	elongatum v. minor	Grun.	2
D2003		Diatoma	hiemale	(Roth) Heib.	3
D2004		Diatoma	hiemale v. mesodon	(Ehr.) Grun.	3
D2005		Diatoma	tenue	Ag.	2
D2006		Diatoma	tenue v. elongatum	Lyngb.	2
D2007		Diatoma	tenue v. pachycephala	Grun.	2
D2008		Diatoma	vulgare	Bory	3
D2009		Diatoma	vulgare v. breve	Grun.	3
D2010		Diatoma	vulgare v. linearis	V. H.	3
D2011		Diatoma	vulgare v. ovalis	(Fricke) Hust.	3
D2012	D2008	Diatoma	vulgare v. producta	Grun.	3
D2100		Diatomella	balfouriana	Grev.	3
D2200		Didymosphenia	geminata	(Lyngb.) M. Schmidt	3
D2300		Diploneis	elliptica	(Kutz.) Cl.	3
D2301		Diploneis	finnica	(Ehr.) Cl.	3
D2302		Diploneis	marginestriata	Hust.	3
D2303		Diploneis	oblongella	(Naeg. ex Kutz.) Ross	3
D2304		Diploneis	oculata	(Breb.) Cl.	3
D2305		Diploneis	oculata v. linearis	Gallik	3
D2306		Diploneis	ostracodarum	(Pant.) Jur.	3
D2307	D2310	Diploneis	pseudovalis	Hust.	2
D2308		Diploneis	puella	(Schum.) Cl.	2
D2309		Diploneis	smithii	(Breb. ex W. Sm.) Cl.	2
D2310		Diploneis	smithii v. pumila	(Grun.) Hust.	2
D2400		Entomoneis	alata	(Ehr.) Ehr.	2
D2401		Entomoneis	ornata	(J.W. Bail.) Reim.	1
D2402		Entomoneis	paludosa	(W. Sm.) Reim.	2
D2403		Entomoneis	robusta	(McCall) Reim.	2
D2500		Epithemia	adnata	(Kutz.) Breb.	2
D2501		Epithemia	adnata v. minor	(Perag. ex Herib.) Patr.	2
D2502		Epithemia	adnata v. porcellus	(Kutz.) Patr.	2
D2503		Epithemia	adnata v. proboscidea	(Kutz.) Patr.	2
D2504		Epithemia	adnata v. saxonica	(Kutz.) Patr.	
D2505		Epithemia	argus	(Ehr.) Kutz.	2
D2506		Epithemia	argus v. alpestris	Grun.	2

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D2507		Epithemia	argus v. longicornis	(Ehr.) Grun.	2
D2508		Epithemia	argus v. protracta	A. Mayer	2
D2509		Epithemia	emarginata	Andrews	
D2510		Epithemia	muelleri	Fricke	
D2511		Epithemia	ocellata	(Ehr.) Kutz.	
D2512		Epithemia	reichelti	Fricke	
D2513		Epithemia	smithii	Carruthers	
D2514		Epithemia	sorex	Kutz.	3
D2515		Epithemia	turgida	(Ehr.) Kutz.	3
D2516		Epithemia	turgida v. granulata	(Ehr.) Brun	3
D2517		Epithemia	turgida v. westermannii	(Ehr.) Grun.	3
D2518	D2500	Epithemia	zebra	(Ehr.) Kutz.	
D2519	D2504	Epithemia	zebra v. saxonica	(Kutz.) Grun.	
D2600		Eunotia	arcus	Ehr.	
D2601		Eunotia	arcus v. bidens	Grun.	
D2602		Eunotia	curvata	(Kutz.) Lagerst.	
D2603		Eunotia	diodon	Ehr.	
D2604		Eunotia	exigua	(Breb. ex Kutz.) Rabh.	
D2605		Eunotia	flexuosa	Breb. ex Kutz.	
D2606		Eunotia	glacialis	Meist.	
D2607		Eunotia	hexaglyphis	Ehr.	
D2608		Eunotia	incisa	W. Sm. ex Greg.	
D2609		Eunotia	maior	(W. Sm.) Rabh.	
D2610		Eunotia	monodon	Ehr.	
D2625		Eunotia	muscicola	Krasske	3
D2611		Eunotia	neagelii	Migula	
D2612		Eunotia	pectinalis	(O. F. Mull.) Rabh.	
D2613		Eunotia	pectinalis v. minor	(Kutz.) Rabh.	
D2614	D2612	Eunotia	pectinalis v. stricta	(Rabh.) V.H.	
D2615		Eunotia	perpusilla	Grun.	
D2616		Eunotia	polydentula	Brun	
D2617		Eunotia	praerupta	Ehr.	
D2618		Eunotia	praerupta v. bidens	(Ehr.) Grun.	
D2619		Eunotia	rostellata	Hust. ex Patr.	
D2620		Eunotia	septentrionalis	Ostr.	
D2621		Eunotia	suecica	A. Cl.	
D2622		Eunotia	tenella	(Grun.) Cl.	
D2623		Eunotia	valida	Hust.	
D2624		Eunotia	vanheurckii	Patr.	
D2700		Fragilaria	alpestris	Krasske	
D2701	D2738	Fragilaria	atomus	Hust.	3
D2702		Fragilaria	bicapitata	A. Mayer	
D2703		Fragilaria	brevistriata	Grun.	3
D2704		Fragilaria	brevistriata v. capitata	Herib.	3
D2705		Fragilaria	brevistriata v. inflata	(Pant.) Hust.	3
D2706		Fragilaria	capucina	Desm.	2
D2707		Fragilaria	capucina v. acuta	Grun. in V.H.	2
D2708		Fragilaria	capucina v. lanceolata	Grun. in V.H.	2
D2709		Fragilaria	capucina v. mesolepta	Rabh.	2
D2710		Fragilaria	construens	(Ehr.) Grun.	3
D2711		Fragilaria	construens v. binodis	(Ehr.) Grun.	3
D2712		Fragilaria	construens v. exigua	(W. Sm.) Schulz	3
D2713		Fragilaria	construens v. pumila	Grun.	3
D2714		Fragilaria	construens v. subsalina	Hust.	3
D2715		Fragilaria	construens v. venter	(Ehr.) Grun.	3
D2716		Fragilaria	crotonensis	Kitton	3

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D2717		Fragilaria	crotonensis v. oregona	Sov.	3
D2738		Fragilaria	exigua	Grun.	3
D2718	D2730	Fragilaria	intermedia	Grun. in V.H.	
D2719		Fragilaria	lapponica	Grun.	
D2720		Fragilaria	leptostauron	(Ehr.) Hust.	3
D2721		Fragilaria	leptostauron v. dubia	(Grun.) Hust.	3
D2722		Fragilaria	leptostauron v. rhomboides	Grun.	3
D2737		Fragilaria	nanana	Lange-Bertalot	3
D2723		Fragilaria	nitzschioides	Grun.	3
D2724	D2705	Fragilaria	pantocsekii	A. Cl.	
D2725		Fragilaria	parasitica v. subconstricta	Grun. in V.H.	
D2726		Fragilaria	pinnata	Ehr.	3
D2727		Fragilaria	pinnata v. intercedens	(Grun.) Hust.	3
D2728		Fragilaria	pinnata v. lancettula	(Schum.) Hust.	3
D2729	D2733	Fragilaria	producta	(Lagst.) Grun.	
D2740		Fragilaria	robusta	(Fusey) Manguin	3
D2730		Fragilaria	vaucheriae	(Kutz.) Peters.	2
D2731		Fragilaria	vaucheriae v. capitellata	(Grun.) Patr.	2
D2732		Fragilaria	vaucheriae v. continua	A. Cl.	2
D2733		Fragilaria	virescens	Ralfs	3
D2734		Fragilaria	virescens v. capitata	Ostr.	3
D2735		Fragilaria	virescens v. elliptica	Hust.	3
D2736		Fragilaria	virescens v. mesolepta	Rabh.	3
D2739		Fragilaria	zeilleri	Heribaud	2
D2850		Frustulia	rhomboides	(Ehr.) DeT.	3
D2851		Frustulia	rhomboides v. amphipleuroides	(Grun.) Cl.	3
D2852		Frustulia	rhomboides v. capitata	(A. Mayer) Patr.	3
D2853		Frustulia	rhomboides v. crassinervia	(Breb. ex W.Sm.) Ross	3
D2854		Frustulia	rhomboides v. saxonica	(Rabh.) DeT.	3
D2858		Frustulia	spicula	Amosse	3
D2855		Frustulia	vulgaris	(Thwaites) DeT.	2
D2856		Frustulia	vulgaris v. capitata	Krasske	2
D2857		Frustulia	weinholdii	Hust.	3
D2950		Gomphoneis	eriense	(Grun.) Skv. et Meyer	3
D2954		Gomphoneis	eriense v. variabilis	Kociolek et Stoermer	3
D2951		Gomphoneis	herculeana	(Ehr.) Cl.	3
D2953		Gomphoneis	herculeana v. robusta	(Grun.) Cl.	3
D2952		Gomphoneis	herculeana v. septiceps	M. Schmidt	3
D2955		Gomphoneis	minuta	(Stone) Kociolek & Stoermer	3
D3050		Gomphonema	abbreviatum	Ag.	
D3051		Gomphonema	acuminatum	Ehr.	
D3052	D3066	Gomphonema	acuminatum v. brebissonii	(Kutz.) Cl.	
D3053	D3051	Gomphonema	acuminatum v. coronata	(Ehr.) W. Sm.	
D3054		Gomphonema	affine	Kutz.	
D3055	D3123	Gomphonema	affine v. insigne	(Greg.) Andrews	
D3056		Gomphonema	angustatum	(Kutz.) Rabh.	2
D3057		Gomphonema	angustatum v. citera	(Hohn et Hellerm.) Patr.	2
D3058		Gomphonema	angustatum v. intermedia	Grun.	2
D3059	D3058	Gomphonema	angustatum v. obesa	Lauby	2
D3060		Gomphonema	angustatum v. obtusatum	(Kutz.) Grun.	2
D3061		Gomphonema	angustatum v. productum	Grun.	2
D3062		Gomphonema	angustatum v. sarcophagus	(Greg.) Grun.	2
D3063		Gomphonema	angustatum v. undulata	(Greg.) Grun.	2
D3119		Gomphonema	angustum	Agardh	3
D3124		Gomphonema	augur	Ehr.	2
D3064	D3119	Gomphonema	bohemicum	Reichelt et Fricke	3

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D3065		Gomphonema	brasiliense	Grun.	
D3066		Gomphonema	brebissonii	(Kutz.)	
D3120		Gomphonema	clavatum	Ehr.	2
D3067		Gomphonema	clevei	Fricke	3
D3068		Gomphonema	consector	Hohn et Hellerm.	
D3069	D3114	Gomphonema	constrictum	Ehr.	3
D3070	D3115	Gomphonema	constrictum v. capitatum	(Ehr.) V.H.	3
D3071		Gomphonema	cumrhis	Hohn et Hellerm.	
D3072	D3119	Gomphonema	dichotomum	Kutz.	3
D3073		Gomphonema	dubravicense	Pant.	
D3074		Gomphonema	gracile	Ehr. emend. V.H.	2
D3075	D3074	Gomphonema	gracile v. aurita	(Braun) Cl.	
D3076		Gomphonema	grunowii	Patr.	
D3077		Gomphonema	hedinii	Hust.	3
D3078		Gomphonema	helveticum	Brun	
D3079		Gomphonema	helveticum v. tenuis	(Fricke) Hust.	
D3123		Gomphonema	insigne	Gregory	3
D3080		Gomphonema	instabilis	Hohn et Hellerm.	
D3081	D3119	Gomphonema	intricatum	Kutz.	3
D3082		Gomphonema	intricatum v. bohemicum	(Reichelt et Fricke) Cl.	3
D3083		Gomphonema	intricatum v. dichotoma	(Kutz.) Grun.	3
D3084		Gomphonema	intricatum v. diminutum	A. Cl.	
D3085		Gomphonema	intricatum v. minor	Skvortzow	
D3086		Gomphonema	intricatum v. pulvinatum	(Braun) Grun.	
D3087	D3122	Gomphonema	intricatum v. pumila	Grun. in V. H.	3
D3088		Gomphonema	intricatum v. vibrio	(Ehr.) Cl.	
D3089	D3076	Gomphonema	lanceolatum	(Ehr.) Kutz.	
D3090	D3120	Gomphonema	longiceps	Ehr.	2
D3091	D3120	Gomphonema	longiceps v. subclavata f. gracillis	Hust.	2
D3092		Gomphonema	manubrium	Fricke	
D3118		Gomphonema	minutum	(Ag.) Ag.	3
D3093		Gomphonema	olivaceoides	Hust.	3
D3094		Gomphonema	olivaceoides v. densestriata	Foged	3
D3095		Gomphonema	olivaceum	(Lyngb.) Kutz.	3
D3096		Gomphonema	olivaceum v. calcareum	(Cl.) Cl.	3
D3097		Gomphonema	olivaceum v. minutissima	Hust.	3
D3098		Gomphonema	parvulum	(Kutz.)	1
D3099	D3098	Gomphonema	parvulum v. micropus	(Kutz.) Cl.	1
D3100	D3098	Gomphonema	parvulum v. subelliptica	Cl.	1
D3122		Gomphonema	pumilum	(Grun.) Reichardt & Lange-Bertalot	3
D3101		Gomphonema	quadripunctatum	(Ostr.) Wisl.	3
D3102		Gomphonema	semiapertum	Grun.	
D3103	D3104	Gomphonema	septata	Moghadam	3
D3104		Gomphonema	septum	Moghadam	3
D3105		Gomphonema	simus	Hohn et Hellerm.	
D3106		Gomphonema	sphaerophorum	Ehr.	
D3107		Gomphonema	staurophorum	(Pant.) A. Cl.	
D3108	D3120	Gomphonema	subclavatum	(Grun.) Grun.	2
D3109		Gomphonema	subclavatum v. commutatum	(Grun.) A. Mayer	2
D3110		Gomphonema	subclavatum v. mexicanum	(Grun.) Patr.	2
D3111		Gomphonema	subtile	Ehr.	
D3112	D3118	Gomphonema	tenellum	Kutz.	3
D3113		Gomphonema	tergestinum	(Grun.) Fricke	
D3114		Gomphonema	truncatum	Ehr.	3
D3115		Gomphonema	truncatum v. capitatum	(Ehr.) Patr.	3
D3116		Gomphonema	truncatum v. elongata	(Perag. et Herib.) Patr.	3

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D3121		Gomphonema	utae	Lange-Bertalot & Reichardt	2
D3117		Gomphonema	ventricosum	Gregory	
D3200		Gyrosigma	acuminatum	(Kutz.) Rabh.	3
D3201		Gyrosigma	attenuatum	(Kutz.) Rabh.	3
D3202		Gyrosigma	attenuatum v. hippocampus	(W. Sm.) A. Cl.	3
D3203		Gyrosigma	exilis	(Grun.) Reim.	
D3204		Gyrosigma	eximium	(Thwaites) Boyer	2
D3205		Gyrosigma	macrum	(W. Sm.) Griff. et Henfr.	2
D3206		Gyrosigma	obtusatum	(Sulliv. et Wormley) Boyer	
D3207		Gyrosigma	peisonis	(Grun.) Hust.	
D3208	D3205	Gyrosigma	prolongatum	(W. Sm.) Cl.	
D3209		Gyrosigma	scalproides	(Rabh.) Cl.	
D3210		Gyrosigma	sciotense	(Sulliv. et Wormley) Cl.	
D3211		Gyrosigma	spencerii	(Quek.) Griff. et Henfr.	2
D3212		Gyrosigma	spencerii v. curvula	(Grun.) Reim.	2
D3213		Gyrosigma	wormleyi	(Sulliv.) Boyer	
D3300		Hannaea	arcus	(Ehr.) Patr.	3
D3301		Hannaea	arcus v. amphioxys	(Rabh.) Patr.	3
D3400		Hantzschia	amphioxys	(Ehr.) Grun.	2
D3401		Hantzschia	amphioxys f. capitata	O. Mull.	2
D3402		Hantzschia	amphioxys v. maior	Grun.	2
D3403		Hantzschia	amphioxys v. vivax	(Hantzsch) Grun.	2
D3404		Hantzschia	elongata	(Hantzsch) Grun.	
D3405		Hantzschia	virgata	(Roper) Grun.	
D3406		Hantzschia	virgata v. capitellata	Hust.	
D3407		Hantzschia	vivax	(W. Sm.) M. Perag.	
D3500		Mastogloia	braunii	Grun.	2
D3501		Mastogloia	elliptica	(Ag.) Cl.	2
D3502		Mastogloia	elliptica v. danseii	(Thwaites) Cl.	2
D3503		Mastogloia	grevillei	W. Sm.	2
D3504		Mastogloia	smithii	Thwaites ex W. Sm.	2
D3505		Mastogloia	smithii v. amphicephala	Grun.	2
D3506		Mastogloia	smithii v. lacustris	Grun.	2
D3600	D0551	Melosira	ambigua	(Grun.) O. Mull.	
D3601	D0552	Melosira	distans	(Ehr.) Kutz.	3
D3602	D0558	Melosira	distans v. africana	O. Mull.	3
D3603	D0550	Melosira	distans v. alpigena	Grun. in V.H.	3
D3604	D0556	Melosira	distans v. lirata	(Ehr.) Bethge	3
D3605	D0558	Melosira	distans v. pfaffiana	(Reinsch) Grun.	3
D3606		Melosira	fennoscandica	A. Cl.	
D3607	D0553	Melosira	granulata	(Ehr.) Ralfs	3
D3608	D0553	Melosira	granulata v. angustissima	Muller	3
D3609	D0554	Melosira	islandica	O. Mull.	3
D3610	D0555	Melosira	italica	(Ehr.) Kutz.	3
D3611	D0555	Melosira	italica v. subarctica	Muller	3
D3612	D0555	Melosira	italica v. valida	Grun. in V.H.	3
D3613		Melosira	juergensi	Ag.	
D3614	D0556	Melosira	lirata	(Ehr.) Kutz.	
D3615	D0557	Melosira	perglabra	Ostr.	
D3616	D4550	Melosira	roeseana	Rabh.	2
D3617		Melosira	undulata	(Ehr.) Kutz.	
D3618		Melosira	varians	Ag.	2
D3700		Meridion	circulare	(Grev.) Ag.	3
D3701		Meridion	circulare v. constrictum	(Ralfs) V.H.	3
D3800		Navicula	abiskoensis	Hust.	
D3801		Navicula	aboensis	(Cl.) Hust.	

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ID #:	SYN. OF	GENUS:	SPECIES/VARIETY:	AUTHOR:	POL.CL.
D3802		Navicula	absoluta	Hust.	
D3803		Navicula	acceptata	Hust.	
D3804		Navicula	accomoda	Hust.	1
D3805		Navicula	aequorea	Hust.	
D3806		Navicula	aerophila	Krasske	
D4077		Navicula	agrestis	Hustedt	1
D3807		Navicula	americana	Ehr.	3
D4074		Navicula	ammophila	Grunow	2
D3808		Navicula	amphibola	Cl.	
D3809		Navicula	amphipleuroides	Hust.	
D3810		Navicula	anglica	Ralfs	
D3811		Navicula	anglica v. subsalsa	(Grun.) Cl.	
D3812		Navicula	angusta	Grun.	
D4070		Navicula	aquaedurae	Lange-Bertalot	2
D3813		Navicula	arenaria	Donk.	
D3814		Navicula	arvensis	Hust.	2
D3815		Navicula	atomus	(Kutz.) Grun.	1
D3816	D4030	Navicula	auriculata	Hust.	1
D3817		Navicula	aurora	Sov.	3
D3818		Navicula	avenacea	Breb. ex Grun.	2
D3819		Navicula	bacilloides	Hust.	
D3820		Navicula	bacillum	Ehr.	3
D3821		Navicula	bicapitellata	Hust.	
D3822		Navicula	bicephala	Hust.	3
D3823		Navicula	biconica	Patr.	
D3824	D4205	Navicula	binodis	Ehr.	
D3825		Navicula	bryophila	Petersen	3
D3826		Navicula	bulnheimii	Grun.	
D3827		Navicula	canalis	Patr.	
D3828		Navicula	capitata	Ehr.	2
D3829		Navicula	capitata v. hungarica	(Grun.) Ross	2
D3830		Navicula	capitata v. luneburgensis	(Grun.) Patr.	2
D4056		Navicula	capitatoradiata	Germain	2
D3831		Navicula	cari	Ehr.	2
D3832		Navicula	cascadensis	Sov.	3
D4082		Navicula	cataractarheni	Lange-Bertalot	3
D3833		Navicula	cincta	(Ehr.) Ralfs	2
D4061	D3833	Navicula	cincta forma minuta	Grun. in V.H.	2
D3834	D4042	Navicula	cincta v. rostrata	Reim.	1
D3835		Navicula	circumtexta	Meist. ex Hust.	1
D3836		Navicula	citrus	Krasske	3
D3837		Navicula	clamans	Hust.	
D3838		Navicula	clementis	Grun.	2
D3839		Navicula	clementis v. linearis	Brander	2
D3840		Navicula	cocconeiformis	Greg. ex Grev.	3
D3841	D3956	Navicula	complanatoides	Hust.	
D3842		Navicula	confervacea v. peregrina	(W. Sm.) Grun.	2
D3843		Navicula	contempta	Krasske	
D3844		Navicula	contenta	Grun.	2
D3845		Navicula	contenta f. biceps	(Arnott) Grun.	2
D3846		Navicula	contenta f. parallela	Petersen	2
D3847		Navicula	convergens	Patr.	
D3848		Navicula	costulata	Grun.	
D3849		Navicula	crucicula	(W. Sm.) Donk.	
D3850		Navicula	cryptocephala	Kutz.	3
D3854	D4073	Navicula	cryptocephala f. terrestris	Lund	2

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D3851		Navicula	cryptocephala v. exilis	(Kutz.) Grun.	3
D3852		Navicula	cryptocephala v. perminuta	Grun.	
D3853	D4042	Navicula	cryptocephala v. subsalina	Hust.	1
D3855	D4066	Navicula	cryptocephala v. veneta	(Kutz.) Rabh.	2
D3856	D4042	Navicula	cryptocephaloides	Hust.	1
D4055		Navicula	cryptotenella	Lange-Bertalot	2
D3857		Navicula	cuspidata	(Kutz.) Kutz.	2
D3858		Navicula	cuspidata v. heribaudii	Perag. in Herib.	2
D3859		Navicula	cuspidata v. major	Meist.	2
D3860		Navicula	cuspidata v. obtusa	Patr.	2
D3861		Navicula	decussis	Ostr.	3
D3862		Navicula	detenta	Hust.	3
D3863	D3870	Navicula	dicephala	(Ehr.) W. Sm.	
D3864		Navicula	difficillima	Hust.	3
D3865		Navicula	digitoradiata	(Greg.) A. Schmidt	
D4062	D3833	Navicula	digitoradiata var. minima	Cleve-Euler	
D3866	D4081	Navicula	digna	Hust.	3
D3867		Navicula	disjuncta	Hust.	
D3868		Navicula	disputans	Patr.	
D3869	D4030	Navicula	dissipata	Hust.	
D4067		Navicula	durrenbergiana	Hustedt	1
D4080		Navicula	eldrigiana	Carter	2
D3870		Navicula	elginensis	(Greg.) Ralfs	3
D3871		Navicula	elginensis v. rostrata	(A. Mayer) Patr.	3
D3872		Navicula	elmorei	Patr.	
D4065		Navicula	enigmatica	Germain	3
D4063		Navicula	erifuga	Lange-Bertalot	2
D3873		Navicula	exigua	Greg. ex Grun.	
D3874		Navicula	exigua v. capitata	Patr.	
D3875		Navicula	explanata	Hust.	
D3876	D1675	Navicula	falaisiensis	Grun. in V.H.	
D3877		Navicula	farta	Hust.	
D3878		Navicula	fenestrella	Hust.	
D3879		Navicula	festiva	Krasske	
D3880		Navicula	flavasinus	Moghadam	
D3881	D3883	Navicula	fragilarioides	Krasske	
D3882	D4019	Navicula	frugalis	Hust.	1
D3883		Navicula	gallica	(W. Sm.) V.H.	2
D3884	D3883	Navicula	gallica v. montana	Bahls	2
D3885		Navicula	gastrum	(Ehr.) Kutz.	
D3886		Navicula	gastrum v. signata	Hust.	
D3887		Navicula	gaufinii	Moghadam	
D3888		Navicula	gemmifera	Simonsen	
D3889		Navicula	goersii	Bahls	2
D3890		Navicula	gottlandica	Grun.	
D3891	D4034	Navicula	gracilis	Ehr.	3
D3892		Navicula	graciloides	A. Mayer	
D3893		Navicula	gregaria	Donk.	2
D3894		Navicula	grimmei	Krasske	
D3895		Navicula	gysingensis	Foged	
D3896		Navicula	halophila	(Grun.) Cl.	2
D3897		Navicula	halophila f. tenuirostris	Hust.	2
D4078		Navicula	halophilioides	Hustedt	1
D3898		Navicula	hambergii	Hust.	
D3899		Navicula	harderi	Hust.	
D3900		Navicula	hassiaca	Krasske	

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D3901	D3833	Navicula	heufleri	Grun.	2
D3902	D4063	Navicula	heufleri v. leptocephala	(Breb. ex Grun.) Perag.	2
D3903		Navicula	hungarica v. linearis	Ostr.	
D3904		Navicula	hustedtii	Krasske	
D3905		Navicula	ignota	Krasske	2
D3906		Navicula	ignota v. anglica	Lund	2
D3907		Navicula	incerta	Grun.	
D4058		Navicula	incertata	Lange-Beratlot	
D3908		Navicula	inflexa	(Greg.) Ralfs	
D3909		Navicula	ingrata	Krasske	
D3910		Navicula	insociabilis	Krasske	
D3911		Navicula	insociabilis v. dissipatoides	Hust.	
D3912		Navicula	integra	(W. Sm.) Ralfs	
D3913		Navicula	iranensis	Hust.	
D3914		Navicula	jaagii	Meister	2
D3915		Navicula	jaernefeltii	Hust.	
D3916		Navicula	keeleyi	Patr.	
D3917		Navicula	kotschyi	Grun.	
D3918		Navicula	laevissima	Kutz.	3
D3919		Navicula	laevissima f. fusticulus	(Ostr.) Camburn	3
D3920		Navicula	lamii	Manguin	1
D3921	D4069	Navicula	lanceolata	(Ag.) Kutz.	2
D4068		Navicula	lanceolata	(Agardh) Ehr.	2
D3922		Navicula	latens	Krasske	
D3923		Navicula	laterostrata	Hust.	
D4075		Navicula	libonensis	Schoemann	2
D3924		Navicula	limatoides	Hust.	
D3925		Navicula	longirostris	Hust.	
D4073		Navicula	lundii	Reichardt	2
D3926		Navicula	lundstromii	Cl.	
D3927	D4019	Navicula	luzonensis	Hust.	1
D4081		Navicula	medioconvexa	Hustedt	3
D3928		Navicula	menisculus	Schumann	2
D3929		Navicula	menisculus v. upsaliensis	(Grun.) Grun.	2
D4076		Navicula	microdigitoradiata	Lange-Bertalot	2
D3930		Navicula	minima	Grun.	1
D3931		Navicula	minima v. pseudofossilis	(Krasske) Reim.	1
D3932		Navicula	minimoides	Manguin	
D3933		Navicula	minnewaukonensis	Elmore	
D3934		Navicula	minuscula	Grun.	1
D3935		Navicula	minuta	(Cl.) A. Cl.	
D4079		Navicula	molestiformis	Hustedt	1
D3936		Navicula	mollissima	Hust.	
D3937		Navicula	monoculata	Hust.	1
D3938		Navicula	montana	Moghadam	
D3939		Navicula	mournei	Patr.	
D3940	D3934	Navicula	muralis	Grun.	1
D3941		Navicula	mutica	Kutz.	2
D3942		Navicula	mutica v. cohnii	(Hilse) Grun.	2
D3943		Navicula	mutica v. undulata	(Hilse) Grun.	2
D3944		Navicula	muticopsis	V.H.	
D3945		Navicula	neoventricosa	Hust.	
D3946		Navicula	notanda	Pantocsek	
D3947		Navicula	notha	Wallace	2
D3948		Navicula	oblonga	(Kutz.) Kutz.	2
D3949		Navicula	odiosa	Wallace	1

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D3950		Navicula	omissa	Hust.	
D3951		Navicula	orbiculata	Patr.	
D3952		Navicula	paludosa	Hust.	
D3953		Navicula	paratunkae	Petersen	
D3954		Navicula	parva	(Menegh.) A. Cl.	
D3955		Navicula	paucivisitata	Patr.	
D3956		Navicula	pavillardii	Hust.	
D3957		Navicula	pelliculosa	(Breb. ex Kutz.) Hilse	1
D3958		Navicula	peratomus	Hust.	
D3959		Navicula	peregrina	(Ehr.) Kutz.	2
D3961		Navicula	peregrina f. minor	Kolbe	2
D3960		Navicula	peregrina v. lanceolata	Skvortzow	2
D3962	D4019	Navicula	perparva	Hust.	1
D3963		Navicula	perpusilla	(Kutz.) Grun.	
D3964		Navicula	peticolasii	M. Perag.	
D3965		Navicula	phyllepta	Kutz.	2
D3966		Navicula	placentula	(Ehr.) Kutz.	
D3967		Navicula	placentula f. rostrata	A. Mayer	
D3968		Navicula	platystoma	Ehr.	
D3969		Navicula	protracta	Grun.	2
D3970		Navicula	protracta f. subcapitata	(Wislouch et Poretzky) Hust.	
D3971	D3815	Navicula	pseudatomus	Lund	
D3972		Navicula	pseudoarvensis	Hust.	
D4072		Navicula	pseudolanceolata	Lange-Bertalot	3
D3973		Navicula	pseudoreinhardtii	Patr.	
D3974		Navicula	pseudoscutiformis	Hust.	
D3975		Navicula	pseudosilicula f. olympica	Sov.	3
D3976		Navicula	pupula	Kutz.	2
D3981		Navicula	pupula f. rostrata	Hust.	2
D3977		Navicula	pupula v. capitata	Skv. et Meyer	2
D3978		Navicula	pupula v. elliptica	Hust.	2
D3979		Navicula	pupula v. mutata	(Krasske) Hust.	2
D3980		Navicula	pupula v. rectangularis	(Greg.) Grun.	2
D3982		Navicula	pusio	Cl.	
D3983		Navicula	pygmaea	Kutz.	2
D3984		Navicula	radiosa	Kutz.	3
D3985		Navicula	radiosa v. parva	Wallace	
D3986		Navicula	radiosa v. subrostrata	Cl.	
D3987	D4055	Navicula	radiosa v. tenella	(Breb. ex Kutz.) Grun.	2
D4060		Navicula	recens	(Lange-Bertalot) Lange-Bertalot	2
D4066		Navicula	reichardtiana	Lange-Bertalot	2
D3988		Navicula	reinhardtii	(Grun.) Grun.	
D3989		Navicula	rhynchocephala	Kutz.	3
D3990		Navicula	rhynchocephala v. amphiceros	(Kutz.) Grun.	3
D3991		Navicula	rhynchocephala v. germainii	(Wallace) Patr.	3
D4071		Navicula	rhynchotella	Lange-Bertalot	2
D3992	D0093	Navicula	rotaeana	(Rabh.) Grun.	3
D3993		Navicula	rotunda	Hust.	
D3994		Navicula	salinarum	Grun.	1
D3995	D4056	Navicula	salinarum v. intermedia	(Grun.) Cl.	2
D3996		Navicula	salinarum v. tenuirostris	A. Cl.	
D4059	D4058	Navicula	salinicola	Hustedt	1
D3997		Navicula	schmassmannii	Hust.	
D3998		Navicula	schonfeldii	Hust.	
D4064		Navicula	schroeterii	Meister	2
D3999	D4064	Navicula	schroeterii v. escambia	Patr.	2

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D4000		Navicula	scutelloides	W. Sm. ex Greg.	
D4001		Navicula	scutum	(Schumann) V.H.	
D4002		Navicula	secreta	Krasske	
D4003	D3893	Navicula	secreta v. apiculata	Patr.	2
D4004		Navicula	secura	Patr.	
D4005		Navicula	semen	Ehr. emend. Donk.	
D4006		Navicula	semenoides	Hust.	
D4007		Navicula	seminuloides	Hust.	
D4008		Navicula	seminulum	Grun.	1
D4009		Navicula	seminulum v. hustedtii	Patr.	1
D4010		Navicula	seminulum v. radiosa	Hust.	1
D4011	D3896	Navicula	simplex	Krasske	2
D4012		Navicula	simula	Patr.	
D4057	D4066	Navicula	species 2	Lange-Bertalot	2
D4013	D0097	Navicula	subatomoides	Hust.	
D4014		Navicula	subbacillum	Hust.	
D4015		Navicula	subhalophila	Hust.	
D4016		Navicula	subhamulata	Grun.	
D4017		Navicula	subhamulata v. undulata	Hust.	
D4018		Navicula	sublucidula	Hust.	
D4019		Navicula	subminuscula	Manguin	1
D4020		Navicula	subocculta	Hust.	
D4021		Navicula	subrotundata	Hust.	3
D4022		Navicula	subsulcatoides	Hust.	
D4023		Navicula	subtilissima	Cl.	
D4084		Navicula	suchlandtii	Hustedt	3
D4024		Navicula	supralitoralis	Aleem et Hust.	
D4025		Navicula	swaniana	Moghadam	
D4026	D4064	Navicula	symmetrica	Patr.	2
D4027		Navicula	tackei	Hust.	
D4028		Navicula	tantula	Hust.	2
D4029		Navicula	tenelloides	Hust.	1
D4030		Navicula	tenera	Hust.	1
D4031		Navicula	texana	Patr.	
D4032		Navicula	tongatensis	Hust.	
D4033		Navicula	tridentula	Krasske	3
D4034		Navicula	tripunctata	(O.F. Mull.) Bory	3
D4035		Navicula	tripunctata v. schizonemoides	(V.H.) Patr.	3
D4069		Navicula	trivialis	Lange-Bertalot	2
D4036		Navicula	tuscula	Ehr.	3
D4037		Navicula	tuscula f. angulata	Hust.	3
D4038		Navicula	tuscula f. minor	Hust.	
D4039		Navicula	utermohlii	Hust.	
D4040	D0093	Navicula	vanheurckii	Patr.	3
D4041		Navicula	variostriata	Krasske	3
D4042		Navicula	veneta	Kutz.	1
D4043		Navicula	ventralis v. chilensis	Krasske	
D4044		Navicula	verecunda	Hust.	
D4045		Navicula	viridula	(Kutz.) Kutz.	2
D4046	D3818	Navicula	viridula v. avenacea	(Breb. ex Grun.) V.H.	2
D4047		Navicula	viridula v. linearis	Hust.	2
D4048		Navicula	viridula v. rostellata	(Kutz.) Cl.	2
D4049		Navicula	vitabunda	Hust.	
D4050		Navicula	vitabunda v. montana	Moghadam	
D4051		Navicula	vulpina	Kutz.	
D4083		Navicula	wiesneri	Lange-Bertalot	2

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D4052	D3918	Navicula	wittrockii	(Lagst.) A. Cl.	3
D4053	D3918	Navicula	wittrockii v. fennica	A. Cl.	3
D4054		Navicula	zanoni	Hust.	
D4200		Neidium	affine	(Ehr.) Pfitz.	
D4201		Neidium	affine v. amphirhynchus	(Ehr.) Cl.	
D4202		Neidium	affine v. ceylonicum	(Skv.) Reim.	
D4203		Neidium	affine v. hankense	(Skv.) Reim.	
D4204		Neidium	affine v. longiceps	(Greg.) Cl.	
D4205		Neidium	binode	(Ehr.) Hust.	
D4206	D4205	Neidium	binodis	(Ehr.) Hust.	
D4207		Neidium	bisulcatum	(Lagst.) Cl.	
D4208		Neidium	bisulcatum v. baicalense	(Skv. et Meyer) Reim.	
D4209		Neidium	bisulcatum v. subundulatum	(Grun.) Reim.	
D4210		Neidium	dubium	(Ehr.) Cl.	
D4211		Neidium	dubium f. constrictum	Hust.	
D4212		Neidium	hercynicum	A. Mayer	
D4213		Neidium	hercynicum f. subrostratum	Wallace	
D4214		Neidium	iridis	(Ehr.) Cl.	
D4217		Neidium	iridis f. vernalis	Reichelt	
D4215		Neidium	iridis v. amphigomphus	(Ehr.) A. Mayer	
D4216		Neidium	iridis v. ampliatum	(Ehr.) Cl.	
D4218		Neidium	kozlowi	Mereschkowsky	
D4219		Neidium	productum	(W. Sm.) Cl.	
D4220		Neidium	temperei	Reim.	
D4300	D4381	Nitzschia	abridia	Camburn	
D4301		Nitzschia	acicularis	(Kutz.) W. Sm.	2
D4423		Nitzschia	acidoclinata	Lange-Bertalot	3
D4302		Nitzschia	acula	Hantzsch ex Cl. et Grun.	3
D4303		Nitzschia	acuminata	(W. Sm.) Grun.	
D4304	D4302	Nitzschia	acuta	Hantzsch	
D4424		Nitzschia	agnita	Hustedt	1
D4305	D4408	Nitzschia	alexandrina	(Cholnoky) Lange-Bertalot et Simonsen	1
D4428		Nitzschia	alpina	Husedt	3
D4306		Nitzschia	amphibia	Grun.	2
D4307		Nitzschia	amphioxoides	Hust.	
D4308		Nitzschia	angustata	(W. Sm.) Grun.	2
D4309	D4308	Nitzschia	angustata v. acuta	Grun.	2
D4310	D4410	Nitzschia	apiculata	(Greg.) Grun.	2
D4426		Nitzschia	archibaldii	Lange-Bertalot	2
D4408		Nitzschia	aurariae	Cholnoky	1
D4311	D4368	Nitzschia	bacata	Hust.	
D4421		Nitzschia	bacillum	Hustedt	3
D4312		Nitzschia	balatonis	Grun. in V.H.	1
D4313		Nitzschia	bergii	A. Cl.	1
D4314		Nitzschia	bremensis	Hust.	
D4415		Nitzschia	brevissima	Grun.	
D4429		Nitzschia	bryophila	(Hust.) Hust.	3
D4315	D4335	Nitzschia	bulnheimiana	(Rabh.) H.L. Sm.	2
D4316		Nitzschia	capitellata	Hust.	2
D4317		Nitzschia	circumsuta	(Bailey) Grun.	
D4318		Nitzschia	clausii	Hantzsch	2
D4319		Nitzschia	closterium	(Ehr.) W. Sm.	2
D4417		Nitzschia	coarctata	Grun.	1
D4320		Nitzschia	communis	Rabh.	1
D4321		Nitzschia	commutata	Grun.	
D4416		Nitzschia	compressa	(Bailey) Boyer	1

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D4322	D4351	Nitzschia	congolensis	Hust.	
D4410		Nitzschia	constricta	(Kutz.) Ralfs	2
D4323		Nitzschia	denticula	Grun.	3
D4324		Nitzschia	denticula v. curta	Grun.	3
D4325		Nitzschia	desertorum	Hust.	2
D4326		Nitzschia	dissipata	(Kutz.) Grun.	3
D4327		Nitzschia	dubia	W. Sm.	
D4328	D4376	Nitzschia	elliptica	Hust.	1
D4329	D4350	Nitzschia	epiphytica	O. Mull.	2
D4330		Nitzschia	epithemoides	Grun.	
D4331		Nitzschia	fasciculata	Grun.	
D4332		Nitzschia	filiformis	(W. Sm.) V.H.	2
D4333		Nitzschia	flexa	Schumann	
D4334		Nitzschia	fonticola	Grun. in Cl. et Moll.	3
D4425		Nitzschia	fossilis	(Grun.) Grun	2
D4335		Nitzschia	frustulum	(Kutz.) Grun.	2
D4336	D4371	Nitzschia	frustulum v. perminuta	Grun.	3
D4337	D4350	Nitzschia	frustulum v. perpusilla	(Rabh.) Grun.	2
D4338		Nitzschia	frustulum v. subsalina	Hust.	2
D4339	D4418	Nitzschia	gandersheimiensis	Krasske	1
D4340		Nitzschia	goetzeana	O. Mull.	
D4341		Nitzschia	goetzeana v. gracilior	Hust.	
D4342		Nitzschia	gracilis	Hantzsch	2
D4343		Nitzschia	hantzschiana	Rabh.	3
D4344		Nitzschia	heufleriana	Grun.	3
D4345		Nitzschia	hollerupensis	Foged	
D4346	D4368	Nitzschia	holsatica	Hust.	
D4347		Nitzschia	hungarica	Grun.	2
D4348		Nitzschia	hybrida	Grun.	
D4349		Nitzschia	ignorata	Krasske	
D4413		Nitzschia	incognita	Legler & Krasske	2
D4350		Nitzschia	inconspicua	Grun.	2
D4351		Nitzschia	intermedia	Hantzsch ex Cl. et Grun.	3
D4352	D4376	Nitzschia	kutzingiana	Hilse	
D4353		Nitzschia	lacunarum	Hust.	
D4422		Nitzschia	lacuum	Lange-Bertalot	3
D4354		Nitzschia	lanceolata	W. Sm.	
D4412		Nitzschia	leistikowii	Lange-Bertalot	2
D4355		Nitzschia	liebetruthii	Rabh.	3
D4356		Nitzschia	linearis	Ag. (W. Sm.)	2
D4357		Nitzschia	longissima v. chinensis	Grun.	
D4358	D4407	Nitzschia	longissima v. reversa	Grun.	2
D4359		Nitzschia	lorenziana	Grun.	
D4360	D4359	Nitzschia	lorenziana v. subtillis	Grun.	
D4361		Nitzschia	microcephala	Grun.	1
D4362		Nitzschia	montanestris	Camburn	
D4363		Nitzschia	obtusa	W. Sm.	1
D4364	D4414	Nitzschia	obtusa v. scalpelliformis	Grun.	1
D4365		Nitzschia	ovalis	Arnott ex Grun.	1
D4366		Nitzschia	palea	(Kutz.) W. Sm.	1
D4367		Nitzschia	palea v. tenuirostris	Grun.	1
D4368		Nitzschia	paleacea	(Grun.) Grun.	2
D4369		Nitzschia	parasitica		
D4370	D4415	Nitzschia	parvula	Lewis	
D4371		Nitzschia	perminuta	(Grun.) M. Perag.	3
D4409		Nitzschia	perspicua	Cholnoky	1

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D4609		Pinnularia	balfouriana	Grun.	
D4610		Pinnularia	biceps	Greg.	
D4611		Pinnularia	biceps f. petersenii	Ross	
D4612		Pinnularia	borealis	Ehr.	2
D4613		Pinnularia	borealis v. breivicostata	Hust.	2
D4614		Pinnularia	borealis v. rectangularis	Carlson	2
D4615		Pinnularia	braunii v. amphicephala	(A. Mayer) Hust.	
D4616		Pinnularia	brebissonii	(Kutz.) Rabh.	
D4617		Pinnularia	brebissonii v. diminuta	(Grun.) Cl.	
D4618		Pinnularia	burkii	Patr.	
D4619		Pinnularia	cuneata	(Ostr.) A. Cl.	
D4620		Pinnularia	divergentissima	(Grun.) Cl.	
D4621		Pinnularia	flexuosa	Cl.	
D4622		Pinnularia	gentilis	(Donk.) Cl.	
D4623		Pinnularia	gibba	Ehr.	
D4624		Pinnularia	globiceps v. krookei	Grun.	
D4625		Pinnularia	hilseana	Jan.	
D4626		Pinnularia	intermedia	(Lagerst.) Cl.	
D4627		Pinnularia	isostauron	(Ehr.) Cl.	
D4628		Pinnularia	kneuckerii	Hust.	
D4629		Pinnularia	lagerstedtii	(Cl.) A. Cl.	
D4630		Pinnularia	latevittata	Cl.	
D4631		Pinnularia	leptosoma	Grun.	
D4632		Pinnularia	maior	(Kutz.) Rabh.	
D4633		Pinnularia	mesogongyla	Ehr.	
D4634		Pinnularia	mesolepta	(Ehr.) W. Sm.	
D4635		Pinnularia	mesolepta v. angusta	Cl.	
D4636		Pinnularia	microstauron	(Ehr.) Cl.	2
D4637		Pinnularia	microstauron f. biundulata	O. Mull.	2
D4638		Pinnularia	minutissima	Hust.	
D4639		Pinnularia	molaris	Grun.	
D4640		Pinnularia	nodosa	(Ehr.) W. Sm.	
D4641		Pinnularia	obscura	Krasske	
D4642		Pinnularia	pulchra	Ostrup	
D4643		Pinnularia	stauroptera	Grun.	
D4644		Pinnularia	stomatophora	(Grun.) Cl.	
D4645		Pinnularia	streptoraphe	Cl.	
D4646		Pinnularia	subcapitata	Greg.	
D4647		Pinnularia	subcapitata v. paucistriata	(Grun.) Cl.	
D4648		Pinnularia	substomatophora	Hust.	
D4649		Pinnularia	viridis	(Nitzsch) Ehr.	
D4650		Pinnularia	viridis v. commutata	(Grun.) Cl.	
D4651		Pinnularia	viridis v. minor	Cl.	
D4800		Plagiotropis	arizonica		2
D4801		Plagiotropis	lepidoptera v. proboscidea	(Cl.) Reim.	2
D4900		Pleurosigma	delicatulum	W. Sm.	2
D4950		Pleurosira	laevis	(Ehr.) Compere	2
D5000		Rhizosolenia	eriensis	H.L. Smith	3
D5001		Rhizosolenia	eriensis v. morsa	W. & G.S. West	3
D5101		Rhoicosphenia	abbreviata	(C. Agardh) Lange-Bertalot	3
D5100	D5101	Rhoicosphenia	curvata	(Kutz.) Grun.	3
D5200		Rhopalodia	gibba	(Ehr.) O. Mull.	2
D5201		Rhopalodia	gibba v. ventricosa	(Kutz.) H. & M. Perag.	2
D5202		Rhopalodia	gibberula	(Ehr.) O. Mull.	
D5203		Rhopalodia	gibberula v. vanheurckii	O. Mull.	
D5204		Rhopalodia	musculus	(Kutz.) O. Mull.	

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D5205	D5200	Rhopalodia	parallela	(Grun.) O. Mull.	2
D5300		Scoliopleura	peisonis	Grun.	2
D5350		Simonsenia	delognei	(Grun.) Lange-Bertalot	2
D5400		Stauroneis	acuta	W. Sm.	
D5401		Stauroneis	anceps	Ehr.	
D5402		Stauroneis	anceps f. gracilis	Rabh.	
D5403		Stauroneis	anceps f. linearis	(Ehr.) Hust.	
D5404		Stauroneis	fluminea	Patr. et Freese	
D5405		Stauroneis	kriegeri	Patr.	
D5406		Stauroneis	phoenicenteron	(Nitzsch) Ehr.	2
D5407		Stauroneis	phoenicenteron f. gracilis	(Ehr.) Hust.	2
D5408		Stauroneis	smithii	Grun.	
D5409		Stauroneis	smithii v. incisa	Pant.	
D5500		Stenopterobia	intermedia	(Lewis) Breb.	3
D5610		Stephanodiscus	Minutulus	(Kutz.) Cleve & Moller	2
D5600		Stephanodiscus	astraea	(Ehr.) Grun.	3
D5601	D5610	Stephanodiscus	astraea v. minutula	(Kutz.) Grun.	2
D5602		Stephanodiscus	carconensis v. pusilla	Grun.	3
D5603	D1251	Stephanodiscus	dubius	(Fricke) Hust.	
D5604		Stephanodiscus	hantzschii	Grun.	2
D5609		Stephanodiscus	medius	Hakansson	2
D5605	D5609	Stephanodiscus	minutus	Cl. et Moll.	2
D5606		Stephanodiscus	niagarae	Ehr.	3
D5607		Stephanodiscus	subtilis	Van Goor	2
D5608		Stephanodiscus	tenuis	Hust.	2
D5730		Surirella	angusta	Kutz.	1
D5700	D5730	Surirella	angustata	Kutz.	1
D5701		Surirella	biseriata	Breb.	
D5702		Surirella	biseriata v. bifrons	(Ehr.) Hust.	
D5729		Surirella	brebissonii	Krammer & Lange-Bertalot	2
D5703		Surirella	brightwellii	W. Sm.	
D5704		Surirella	capronii	Breb.	
D5731		Surirella	crumena	Breb. ex Kutz.	2
D5705		Surirella	delicatissima	Lewis	
D5706		Surirella	didyma	Kutz.	
D5707		Surirella	gracilis	(W. Sm.) Grun.	
D5708		Surirella	iowensis	Lowe	2
D5732		Surirella	lapponica	A. Cleve	2
D5709		Surirella	linearis	W. Sm.	3
D5710		Surirella	linearis v. constricta	(Ehr.) Grun.	3
D5711		Surirella	linearis v. helvetica	(Brun.) Meister	3
D5728		Surirella	minuta	Breb. in Kutz.	2
D5712		Surirella	ovalis	Breb.	2
D5713	D5729	Surirella	ovata	Kutz.	2
D5714	D5731	Surirella	ovata v. crumena	(Breb.) V. H.	2
D5715	D5728	Surirella	ovata v. pinnata	(W. Sm.)	2
D5716	D5728	Surirella	ovata v. salina	(W. Sm.)	2
D5717		Surirella	ovata v. utahensis	Grun.	
D5718		Surirella	petella	Ehr.	
D5719		Surirella	recedens		
D5720		Surirella	robusta	Ehr.	
D5721		Surirella	robusta v. spendida	(Ehr.) V. H.	
D5722		Surirella	simplex	A. Cl.	
D5723		Surirella	spiralis	Kutz.	2
D5724		Surirella	striatula	Turpin	
D5725		Surirella	tenera	Greg.	

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D5726		Surirella	turgida	W. Sm.	
D5727		Surirella	venusta	Ostr.	
D5800		Synedra	actinastroides	Lemmerm.	
D5801		Synedra	acus	Kutz.	2
D5802		Synedra	amphicephala	Kutz.	
D5803		Synedra	amphicephala v. austriaca	(Grun. in V.H.) Hust.	
D5804		Synedra	capitata	Ehr.	
D5805		Synedra	cyclopum	Brutschy	
D5806		Synedra	cyclopum v. gibbosa	Moghadam	
D5807		Synedra	cyclopum v. robustum	Schulz	
D5808		Synedra	delicatissima	W. Sm.	
D5809		Synedra	delicatissima v. angustissima	Grun.	
D5810		Synedra	demerarae	Grun.	
D5811		Synedra	famelica	Kutz.	2
D5812		Synedra	fasciculata	(Ag.) Kutz.	2
D5813		Synedra	fasciculata v. truncata	(Grev.) Patr.	2
D5814		Synedra	filiformis	Grun.	
D5815		Synedra	filiformis v. exilis	A. Cl.	
D5816		Synedra	goulardi	Breb.	
D5817		Synedra	incisa	Boyer	
D5818		Synedra	mazamaensis	Sov.	3
D5819		Synedra	minuscula	Grun.	
D5820		Synedra	montana	Krasske	
D5821	D2737	Synedra	nana	Meist.	3
D5822		Synedra	parasitica	(W. Sm.) Hust.	2
D5823		Synedra	parasitica v. subconstricta	(Grun.) Hust.	2
D5824		Synedra	pulchella	Ralfs ex Kutz.	2
D5825		Synedra	pulchella v. lacerata	Hust.	2
D5826		Synedra	pulchella v. lanceolata	O'Meara	2
D5827		Synedra	radians	Kutz.	2
D5828		Synedra	rumpens	Kutz.	2
D5829		Synedra	rumpens v. familiaris	(Kutz.) Hust.	2
D5830		Synedra	rumpens v. fragilarioides	Grun.	2
D5831		Synedra	rumpens v. meneghiniana	Grun.	2
D5832		Synedra	rumpens v. scotica	Grun.	2
D5833		Synedra	socia	Wallace	2
D5834		Synedra	tenera	W. Sm.	
D5835		Synedra	ulna	(Nitzsch) Ehr.	2
D5836		Synedra	ulna v. amphirhynchus	(Ehr.) Grun.	2
D5837		Synedra	ulna v. biceps	(Kutz.) Kirchn.	2
D5838		Synedra	ulna v. capitata	Ehr.	2
D5839		Synedra	ulna v. chaseana	Thomas	2
D5840		Synedra	ulna v. contracta	Ostr.	2
D5841		Synedra	ulna v. danica	(Kutz.) V.H.	2
D5842	D5837	Synedra	ulna v. longissima	(W. Sm.) Brun	2
D5843		Synedra	ulna v. oxyrhynchus	(Kutz.) V.H.	2
D5844		Synedra	ulna v. oxyrhynchus f. mediocontracta	Hust.	2
D5845		Synedra	ulna v. ramesi	(Herib.) Hust.	2
D5846		Synedra	ulna v. spathulifera	(Grun.) V.H.	2
D5847		Synedra	ulna v. subaequalis	(Grun.) V.H.	2
D5900		Tabellaria	fenestrata	(Lyngb.) Kutz.	
D5901		Tabellaria	flocculosa	(Roth) Kutz.	
D5902		Tabellaria	quadrisepta	Knuds.	
D6000		Tetracyclus	lacustris	Ralfs	
D6001		Tetracyclus	rupestris	(A. Br.) Grun.	
D6100		Thalassiosira	fluviatilis	Hust.	

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06101		Thalassiosira	pseudonana	(Hust.) H. & H.	2
06102		Thalassiosira	weissflogii	(Grun.) G. Fryxell & Hasle	

Appendix 2. Pollution Tolerance Class Default Values For Diatom Genera Reported From Montana.

Genus	Default Value	*Genus*	Default Value
Achnanthes	3	*Gomphoneis*	3
Amphipleura	2	*Gomphonema*	3
Amphora	2	*Gyrosigma*	2
Anomoeoneis	2	*Hannaea*	3
Asterionella	3	*Hantzschia*	2
Aulacoseira	3	*Mastogloia*	2
Bacillaria	2	*Melosira*	3
Berkella (Frustulia)	3	*Meridion*	3
Biddulphia (Pleurosira)	2	*Navicula*	2
Caloneis	3	*Neidium*	3
Campylodiscus	2	*Nitzschia*	2
Chaetoceros	1	*Opephora*	3
Cocconeis	3	*Orthoseira*	3
Coscinodiscus	3	*Pinnularia*	3
Cyclostephanos	2	*Plagiotropis*	2
Cyclotella	3	*Pleurosigma*	2
Cylindrotheca	2	*Pleurosira*	2
Cymatopleura	2	*Rhizosolenia*	3
Cymbella	3	*Rhoicosphenia*	3
Cymbellonitzschia	3	*Rhopalodia*	2
Denticula	3	*Scoliopleura*	2
Diatoma	3	*Simonsenia*	2
Diatomella	3	*Stauroneis*	3
Didymosphenia	3	*Stenopterobia*	3
Diploneis	3	*Stephanodiscus*	2
Entomoneis	2	*Surirella*	2
Epithemia	2	*Synedra*	3
Eunotia	3	*Tabellaria*	3
Fragilaria	3	*Tetracyclus*	3
Frustulia	3	*Thalassiosira*	2